CONDITIONS FOR BUILDING A TECHNOLOGICAL ADVANTAGE OF SMART ENTERPRISES IN THE AGE OF INDUSTRY 4.0

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Introduction

The world industry is constantly progressing, considering technology's evolution and rapid development. Nevertheless, management knowledge about an organisation's market behaviour is also vital during future development. The industrial revolution, as a definition, means one thing – changes[1]. These fundamental changes are the pace of economic, social, cultural and technological development with all the generated costs. The introduced changes often last a long time due to the continuous evolution of the ideas and concepts, but it is tough to indicate this process's starting point. It is only possible to determine what events have initiated rapid progress, but generally, it is not a simple issue. However, the proper definition of the several factors or solutions that are the fundamental generator of the overall progress is one of the most significant elements which defines the course to pursue. It is also worth thinking of an industrial revolution in a slightly broader context – namely, areas and domains where changes are causing another leap in development. Three necessary fields of changes can be mentioned analysing the previous and current industrial revolutions[2]:

- manufacturing (production, resources, equipment),
- transport (physical and digital, including mobility),
- social changes (urbanization, human relations, research).

The gradual replacement of a worker by machine to facilitate work is introduced step by step. Nevertheless, the mentioned areas and the innovations appearing in them are only sometimes the main components of change. It is particularly evident in the fourth industrial revolution, which resulted from profound global social and technological changes, including the invention of the internet. To understand the causes of the current transformation, let us look at the three previous industrial revolutions from an industrial and social perspective[3].

1 J. De Vries, *The industrial revolution and the industrious revolution*, "The Journal of Economic History" 1994, vol. 54(2), pp. 249–270; P.N. Stearns, *The industrial revolution in world history*, Routledge, New York 2020; R. Goncerz, *Rewolucje krok po kroku*, 2018, https://log24.pl/news/rewolucje-krok-po-kroku/ (accessed: 1.05.2020).

2 A.D. Meyer, G.R. Brooks, J.B. Goes, *Environmental jolts and industry revolutions: Organizational responses to discontinuous change*, "Strategic Management Journal" 1990, vol. 11(4), pp. 93–110; M.C. Jensen, *The modern industrial revolution, exit, and the failure of internal control systems*, "The Journal of Finance" 1993, vol. 48(3), pp. 831–880; A.A. Ismail, R. Hassan, *Technical competencies in digital technology towards industrial revolution 4.0*, "Journal of Technical Education and Training" 2019, vol. 11(3), pp. 56–62; R. Goncerz, *Rewolucje…*

3 V. Guallart, *The Self-Sufficient City: Internet has changed our lives but it hasn't changed our cities, yet*, Actar D, Inc., New York 2014; S.J. Keating, J.C. Leland, L. Cai, N. Oxman, *Toward site-specific and self-sufficient robotic fabrication on architectural scales*, "Science Robotics" 2017, vol. 2(5), eaam 8986;

In human history, the four main stages of industrial revolutions were performed:

Revolution 1.0: The period dating back to the first industrial revolution is from the 18th to the second half of the 19th century. This revolution began in Britain, and the main breakthrough was the discovery of energy characteristics and the use of coal as the leading resource. Thanks to developing and better knowledge of these concepts, a steam machine and a spinning machine were constructed[4]. They invented machines that enabled yarn production on an industrial scale[5]. These discoveries allowed the introduction of highly efficient production as a workstation. In this situation, the reference point was a worker who fully controlled the machine's speed and rhythm, increasing production capacity. The initiated changes enhance the dynamic development of production areas by raising productivity and reducing production costs. The first definition of serial production was introduced at that time. Another aspect was coal as the principal resource on an industrial scale, which allowed mining to flourish. The production of new machinery required more steel, which enabled the metallurgical industry to develop dynamically. A revolution followed transport caused by the growing demand for new production materials, resources and goods due to increased manufacturing needs. Thanks to new opportunities, such as the steam machine and the vital need to gather new markets, rail transport and steam-powered ships were invented. England was seen as a precursor, where profound social changes took place at that time – the abolition of feudal lords and the emergence of a sizeable surplus labour force with no means of subsistence and urban centres' development urbanisation[6].

Revolution 2.0: The second industrial revolution was based on petroleum, a new leading resource with higher caloric value than previously used coal. This property significantly influenced the further development of transport branches by opening new possibilities and extremely limiting coal as the primary transport power source. The second industrial revolution is called by many experts the most groundbreaking one because it was based on the development of didactics and education, thanks to which it was possible to create many branches and new scientific fields, which are still present today. The electricity and chemical industries were initiated with an increasing emphasis on developing research in chemical and physical areas[7]. Specialisation in science, industry and economics was defined for the first time. The introduction of electricity,

A.K. Tyagi, S.U. Aswathy, *Autonomous Intelligent Vehicles (AIV): Research statements, open issues, challenges and road for future*, "International Journal of Intelligent Networks" 2021, no. 2, pp. 83–102; R. Goncerz, *Rewolucje…*

4 E. Brynjolfsson, A. McAfee, *The second machine age: Work, progress, and prosperity in a time of brilliant technologies*, W.W. Norton & Company, New York 2014.

5 D.S. Landes, *The unbound Prometheus: technological change and industrial development in Western Europe from 1750 to the present*, Cambridge University Press, Cambridge 2003.

6 R. Goncerz, *Rewolucje…*

7 M.C. Jensen, *The modern industrial revolution…*

which was a significant factor generating the overall world transformation, has significantly influenced the development of the chemical industry, the automotive industry and the entire transport industry, allowing for a partial replacement of rail transport by increasingly popular road transport. It is becoming very significant to improve the solutions, making precision and quality of craft more crucial. We must remember the numerous social changes that introduced industrialisation and disseminated education. These changes have increased the availability of well-qualified staff and enabled more technologically advanced production machines. The concept of a production line was introduced, where at its end, a complete product ready for use was obtained[8]. The second revolution depended on human ingenuity and was closely linked to the ease of access to resources like the first (as opposed to the third and fourth). The location of raw materials strongly influenced the urbanisation of the areas concerned. This discovery of new resources largely contributed to changes in the surrounding world[9].

Revolution 3.0: The second industrial revolution made it possible to build more complex and technologically advanced machines, which paved the third industrial revolution. The necessary resources were semiconductor chips and integrated circuits. A new technical term, "high tech", was introduced, meaning specialised technology[10]. The main focus was developing new specialisations such as atomistic and computer science to obtain more efficient energy sources and accurate data. The third revolution's innovation is the formation of many specialised scientific doctrines, such as bio and nanotechnology, computerisation, ICT, genetics, medical specialities, or advanced economics in micro and macro terms. These branches are supported by solutions based mainly on knowledge, specialist competencies and further discoveries supported by other technical devices. During the third industrial revolution, the location of resources or energy sources is no longer significant. The key to progress is the location of scientific and technological centres. The combination of seemingly distant fields in such centres gives excellent scientific, industrial, and financial results. Technical innovations allow the creation of automatic production lines, which require less operator service[11]. Apart from the spread of education, the third industrial revolution in the social dimension was the emergence of so-called technopolies – industrial districts where knowledge and innovation are the basic building blocks. It presents how the foundations of the incoming fourth revolution were laid[12].

8 C. Freeman, L. Soete, *The economics of industrial innovation*, Routledge, London 1997.

9 R. Goncerz, *Rewolucje…*

10 H. Chesbrough, A.K. Crowther, *Beyond high tech: early adopters of open innovation in other industries*, "R&D Management" 2006, vol. 36(3), pp. 229–236.

11 F.W. Geels, *From sectoral systems of innovation to socio-technical systems Insights about dynamics and change from sociology and institutional theory*, "Research Policy" 2004, vol. 33(6/7), pp. 897–920.

12 R. Goncerz, *Rewolucje…*

Revolution 4.0: The original name of the new Industrie 4.0 concept was developed based on an award from the German government, which allowed to start work on the "High Tech Strategy" project, which assumed close cooperation of all experts on the development and implementation of the new cutting edge technologies. The project was supported and subsidised by the German government. However, the development of new, sometimes pioneering technologies required time also in 2010, and the "High Tech Strategy" project was transformed and expanded into a new project called "High Tech Strategy 2020". The introduced change was approved in 2012. According to the planned strategy, it was envisaged that Germany should become one of the most significant players in the market for the production and implementation of cyber-physical systems-based solutions. It was assumed that the main objective would be to invest in research and cooperation between scientific and technical teams to provide the right conditions for the continuous development of new solutions. The initiative was taken by the Ministry of Education and Research, which set up a team for this purpose consisting of 21 major research organisations bringing together 661 experts from various fields. The field of study was related to industrial development and new technologies in order to establish new rules and standards related to the implementation of the main principles of the concept of Industry 4.0[13]. After an extensive and in-depth study of all aspects, the first idea in January 2011, called Industrie 4.0. However, it turned out that the prepared proposal was subject to numerous modifications taking into account expert advice and was published in April 2013[14]. The name Industry 4.0 from this moment could be fully considered the beginning of the Fourth Industrial Revolution. The concept was officially introduced and presented to the community at the Hannover Messe in the same year[15].

The requirements of the age of Industry 4.0 could be considered in the following areas: technology, strategy, structural solutions, and social attitudes and competencies are connected with the necessity of transformation of organisations both in the context of changes directed at the implementation of innovative solutions associated with digitalisation and new technologies, as well as changes in management methods. To meet these requirements and be able to exist and stay on the market, organisations are forced to adapt constantly to the new reality, which often requires changes in the strategy of operation and the business model. These changes determine the emergence of a new

13 A. Radziwon, A. Bilberg, M. Bogers, E.S. Madsen, *Evaluation the SMART Factory: Exploring Adaptive and Flexible Manufacturing Solutions*, "Procedia Engineering" 2014, no. 69, pp. 1184–1190.

14 D. Matiskova, *Evaluation of the Effectiveness of Engineering Production Process using Pareto Analysis*, "TEM Journal" 2015, vol. 4(1), pp. 96–101.

15 M. Mindas, S. Bednar, *Mass Customization in the context of Industry 4.0: implications of variety-inducted complexity*, [in:] D. Plinta (ed.), *Advanced Industrial Engineering Industry 4.0*, Wydawnictwo Fundacji Centrum NowychTechnologii, Bielsko-Biała 2016, pp. 21–39.

type of organisation, considered SMART. These organisations use technologies that allow new manufacturing methods and production and information management. These changes aim to improve the organisation's functioning regarding process optimisation, flexibility, rapid response to environmental changes, quality, efficiency, and effectiveness. Meeting these requirements can impact the development of technological potential and building the technological advantage of SMART organisations in the age of Industry 4.0. It can achieve higher levels of technological advantage and, thus, competitive advantage in the age of Industry 4.0.

The analysis of the literature on the subject and the results of secondary research regarding the management of an organisation in the age of Industry 4.0, specific requirements of Industry 4.0, and building technological and competitive advantage has shown that significant cognitive gaps are evident that justify researching the identification of conditions for building technological advantage in SMART enterprises in the age of Industry 4.0. The first theoretical gap is due to needing to define the concepts of technological potential and technological advantage as components of building the competitive advantage of an enterprise. The second empirical gap is due to the need for more research on the analysis and evaluation of the possibility of using and the importance of technological advantage of enterprises as a determinant of building the competitive advantage of SMART enterprises. The methodological gap, on the other hand, results from the need for more operationalisation and standardised methods for measuring enterprises' technological potential and technological advantage, especially those with SMART characteristics. The last perceived practical gap is due to the need for more business practice recommendations to improve enterprises' competitiveness, especially those with SMART characteristics, through appropriately targeted enhancement of their technological potential and building technological advantage.

In an attempt to fill the above cognitive gaps, research problems were formulated, expressed in the form of questions:

- Q1: What are the key requirements of the age of Industry 4.0 for the successful operation of SMART enterprises?
- Q2: What conditions determine the building of the technological advantage of SMART enterprises?
- Q3: How should the level of technological advantage in SMART enterprises be assessed?
- Q4: How do degree of familiarity and scope of application of the requirements of the age of Industry 4.0 affect the level of technological potential in SMART enterprises?
- Q5: How does the level of technological potential development of SMART enterprises affect their level of technological advantage?

- Q6: How does the level of technological advantage affect the level of competitive advantage of SMART enterprises?
- Q7: How to build the technological advantage of SMART enterprises?

The main objective of the scientific monograph was, **identification and characterisation the conditions of technological advantage of SMART enterprises and to assess the dependence of the level of competitive advantage on the level of technological advantage of these enterprises** (MO). The following specific objectives are subordinated to the realisation of the main objective thus formulated:

- O1: Evaluation of the key requirements for SMART enterprises by the age of Industry 4.0 (realised in chapter 1).
- O2: Identification and systematisation of the conditions determining the building of technological advantage in SMART enterprises (realised in chapter 2).
- O3: Creation and operationalisation of a research tool to assess the level of technological advantage of SMART enterprises (realised in chapter 2).
- O4: Identification of the relationship between degree of familiarity and scope of application of the requirements of the age of Industry 4.0 and the level of the technological potential of SMART enterprises (realised in chapter 4).
- O5: Identification of the relationship between the level of technological potential development and the level of technological advantage of SMART enterprises (realised in chapter 4).
- O6: Identification of the relationship between the level of technological advantage and the level of competitive advantage of SMART enterprises (realised in chapter 4).
- O7: Development of a procedure to follow in the process of building technological advantage in SMART enterprises (realised in chapter 4).

Based on the literature review, keeping in mind the objectives of the scientific monograph, both main and specific, as well as the research questions posed, the main hypothesis of the scientific monograph was formulated: **The ability to form a technological advantage in the age of Industry 4.0 increases the effectiveness of the process of building SMART enterprises' competitive advantage** (MH) and four specific hypotheses:

- H1: Degree of familiarity with the requirements of the age of Industry 4.0 supports the development of the technological potential of SMART enterprises.
- H2: Application of solutions compliant with the requirements of the age of Industry 4.0 increases the development level of SMART enterprises' technological potential.
- H3: The higher the level of technological potential development, the higher the level of technological advantage obtained by SMART enterprises in the age of Industry 4.0.
- H4: The higher the level of technological advantage, the higher the level of competitive advantage gained by SMART enterprises in the age of Industry 4.0.

To achieve the set objectives of the study, literature studies and own research were conducted to test the formulated hypotheses. Two survey techniques were used in the empirical research: CAWI (Computer Assisted Web Interview) and CATI (Computer Assisted Telephone Interview). The research tool was a structured and standardised survey questionnaire presented later in the thesis. The appropriate research was preceded by a pilot study among 10 enterprises, which allowed the logic of the questions asked to be checked and the research tool modified. The object of the research was 151 enterprises from the automotive industry functionating in Poland, which were selected randomly to ensure the sample's representativeness and the possibility to generalise the obtained results. The data obtained in the research process were analysed using mixed methods with a quantitative and qualitative perspective in analysis methods.

For the quantitative analysis, advanced statistical tools were used to infer the acceptance and rejection of research hypotheses and to formulate generalisations. The following types of analysis were applied at the data analysis stage: preliminary analysis (descriptive statistics and structure indicators), comparative analysis (ANOVA, Shapiro-Wilk test, Kruskal-Wallis test, Levene's test, Welch's test, post-hoc tests, Bonferroni test, Tamhane's T2 test), dependence analysis (chi-square independence test, Fisher's exact test, Spearman's rank correlation coefficient, Kendall's Tau-c coefficient, Pearson's linear correlation coefficient) and scale reliability analysis (Cronbach's α coefficient).

The qualitative analysis of the data obtained in the research process provided the opportunity to identify and characterise in detail 20 enterprise cases, enabling the development of a procedure to follow in the process of building a technological advantage for the SMART enterprise.

The layout of the scientific monograph is strictly subordinated to the realisation of the objectives of the elaboration, the verification of the set research hypotheses and the answer to the prepared research questions. The scientific monograph begins with an introduction, and then we can distinguish two theoretical parts, which include the first two chapters and an empirical part containing chapters 3 and 4. The scientific monograph ends with a conclusion.

The first chapter, entitled *Organisations management in the age of Industry 4.0*, first discusses the essence of the age of Industry 4.0 in developing this concept and identifies its technological and non-technological requirements. Against this background, the SMART organisation is defined, and its key areas are characterised as open culture, open resources and open knowledge. The final part of this chapter analyses the evolution of the management process in the SMART organisation and presents the business models of the age of Industry 4.0.

The second chapter, entitled *Building the technological advantage of SMART enterprises*, contains in the first part an explanation of the concepts of competitiveness, competitive advantage and the conditions for building the competitive advantage of SMART enterprises in the age of Industry 4.0. The next part of this chapter defines technological advantage, characterises the process of building this advantage, and then presents the conditions for building technological advantage. The chapter concludes with a proposal of the author's tool for assessing the level of technological advantage of SMART enterprises in the age of Industry 4.0.

The third chapter, *Research methodology and characteristics of the researched SMART enterprises* opens with a characterisation of the automotive industry in Poland as an operating environment for the surveyed enterprises and a description of the research procedure, including the research techniques used. It is followed by a discussion of cognitive gaps, research problems defined in the form of questions, the main objective and specific objectives, the main and specific hypotheses and the research model, and the operationalisation of individual variables. The next section of this chapter describes the statistical measures and tools used to analyse the data obtained. The chapter concludes with a characterisation of the enterprises under study.

The fourth chapter of the scientific monograph, entitled *Building a technological advantage in the practice of SMART enterprises – research results* presents the results of empirical research. The first part of the chapter contains a statistical analysis of the data and a comparative analysis of the conditions for building a technological advantage by the SMART enterprises under study, followed by a dependence analysis allowing for the verification of the hypotheses. The last part of this chapter presents the author's procedure for proceeding in the process of building a technological advantage.

The scientific monograph ends with conclusions, research limitations, and recommendations for further research in the analysed area. An integral element of the elaboration are appendices containing a survey questionnaire and a tool for determining a SMART enterprise's current level of technological advantage in the age of Industry 4.0.

1. Organisations management in the age of Industry 4.0

1.1. Specific requirements of the age of Industry 4.0

According to the literature review, sample definitions of Industry 4.0 are presented in Table 1.1. The overall essence of Industry 4.0 comprises the four main design principles: interconnection, information transparency, technical assistance and decentralised decisions.

The first of these is interconnection, and this principle is mainly connected with the communication between machines, sensors, and devices with people via the newest communication channels based on the Internet of Things (IoT) or the Internet of People (IoP). The aim is to create an independent communication network allowing live coverage. Individual separate networks connect to the main communication channel based on advanced internet solutions. The primary purpose of such a connection is an efficient and fast data exchange between devices and operators. This system detects irregularities at the early stages of production and implements new solutions based on Industry 4.0. It also significantly impacts machines' development in communication skills based on the interaction between sensors and devices based on artificial intelligence. Information transparency is directly related to collecting performance and identifying critical areas. Starting from collecting data in information transparency, each operator has unlimited access to all parameters of the performed production processes to predict the appropriate work characteristics at one workstation and the whole production line. This system allows us to make the right decisions based on the analysis of collected data to increase work efficiency and reduce time lost to a minimum. When identifying critical areas through information transparency, the operator will assign appropriate actions in specific production areas to introduce innovations and improvements leading to development based on the latest technologies used in the age of Industry 4.0. Another design principle is technical assistance, which allows the creation of support systems for people through a combination and visualisation of information, creating new solutions for making decisions that solve technical and business problems. These activities generate and implement physical systems to support people by machines in the scope of work and activities too exhausting or directly threatening employees' lives and health. Thanks to such systems, it is possible to maximise productivity in many cases due to unlimited possibilities, limiting the human factor as a workforce. Increasing machines' support also allows for crossing the boundaries of opportunity in many industrial areas, one of the essential elements of implementing and testing innovative technologies under previously unknown working conditions. It also enables mapping laboratory conditions in the real world without exposing third parties. The last design principle of the age of Industry 4.0 is decentralised decisions. It is based on implementing the ability to make independent decisions by devices into cyber-physical systems. This solution makes it possible to categorise activities or operations that the machine operator does not have to accept but can be performed autonomously. Activities related directly to a software update or device optimisation based on the set parameters do not require continuous operator intervention. On the other hand, activities related to technical problems, conflicts between devices and changes in work characteristics should be verified by the operator or delegated to a higher level.

Table 1.1. Proposed definitions of Industry 4.0

Authors	Definition
Piccarozzi, Aquilani, and Gatti, 2018	Industry 4.0 refers to the integration of Internet of Things technologies into industrial value creation enabling manufacturers to harness entirely digitized, connected, SMART, and decentralized value chains[a] able to deliver greater flexibility and robustness to enterprise competitiveness and enable them to build flexible and adaptable business structures [acquiring] the permanent ability for internal evolutionary developments in order to cope with a changing business environment as the result of a purposely formulated strategy implemented over time[b].
Pilloni, 2018	The Industry 4.0 paradigm is based on machines, devices, logistics and humans connected to each other to exchange data, process them and make decisions based upon them, while appropriately coordinating in a ubiquitous and ad hoc manner thanks to M2M communications[c].
Alcácer and Cruz-Machado, 2019	The buzz word "Industry 4.0" has been presented and with it big promises arose to face the latest challenges in manufacturing systems. The impeller Industry 4.0 (I4.0) is enabling and reinforcing this trend using its technologies, changing the way of living, creating new business models and new ways of manufacturing, renewing the industry for the so-called digital transformation.
Horváth and Szabó, 2019	The Fourth Industrial Revolution, which is currently taking place, sets a number of challenges for manufacturing organisations from the technological, organisational and management points of view. With the application of new technologies and the transformation of processes, significant changes are expected in the field of work, and future production systems demand new competencies from employees. Work organisation is expected to become more flexible in time and space, with workflows becoming more transparent, decentralized, and less hierarchical[d].
Bai et al., 2020	Industry 4.0 is purported to be a new paradigm of SMART and autonomous manufacturing. It more profoundly integrates manufacturing operations systems with communication, information and intelligence technologies[e]. Among the litany of benefits, Industry 4.0 can provide manufacturing enterprises with profitable business models, higher efficiency, quality, and improved workplace conditions[f].
Büchi, Cugno, and Castagnoli, 2020	Industry 4.0 is changing enterprises' strategies, organisation, business models, value and supply chains, processes, products, skills, and stakeholder relationships. Industry 4.0 has created new opportunities and vulnerabilities that must be managed and governed to positively impact both business and society[g].

Authors	Definition
Javaid et al., 2020	Industry 4.0 is also known as the fourth industrial revolution, which consists of advance manufacturing and information technologies, to fulfil the customised requirement of different areas of the human being in lesser time. These technologies provide wireless connectivity in the manufacturing and service sector to enhance automation.
Rosin et al., 2020	Industry 4.0 is characterised by the use of intelligent products and processes, enabling autonomous data collection and analysis, and interaction between products, processes, suppliers and customers over the Internet[h].
Ivanov and Dolgui, 2021	Industry 4.0 constitutes a technological framework for adoption of cyber-physical integration principles in manufacturing, logistics, and supply chains.
Ivanov et al., 2021	Industry 4.0 is an integrity of technologies, organisational concepts and management principles underlying a cost-efficient, responsive, resilient and sustainable network, data-driven and dynamically and structurally adaptable to changes in the demand and supply environment through rapid rearrangement and reallocation of its components and capabilities

[a] G. Prause, S. Atari, *On sustainable production networks for Industry 4.0*, "Journal of Entrepreneurship and Sustainability Issues" 2017, vol. 4(4), pp. 421–431.
[b] R. Koether, *Taschenbuch der Logistik*, Carl Hanser Verlag GmbH & Co. KG, Ludwig-Maximilians-Universität München und Münchner Kreis, Leipzig 2006, p. 583.
[c] M. Weyrich, J.P. Schmidt, C. Ebert, *Machine-to-machine communication*, "Software Technology" 2014, no. 31, pp. 19–23.
[d] A. Picot, R. Neuburger, *Arbeit in der digitalen Welt, Zusammenfassung der Ergebnisse der AG1-Projektgruppe anlässlich des IT-Gipfels-Prozesses 2013 und 2014*, Ludwig-Maximilians-Universität München und Münchner Kreis, München 2014.
[e] Y. Wang, H.S. Ma, J.H. Yang, K.S. Wang, *Industry 4.0: a way from mass customization to mass personalization production*, "Advances in Manufacturing" 2017, vol. 5(4), pp. 311–320.
[f] E. Hofmann, M. Rüsch, *Industry 4.0 and the current status as well as future prospects on logistics*, "Computers in Industry" 2017, no. 89, pp. 23–34.
[g] W.W.H. Kagermann, J. Helbig, W. Wahlster, *Recommendations for Implementing the Strategic Initiative Industrie 4.0. Final report of the Industrie 4.0 Working Group*, Forschungsunion, acatech, München 2013.
[h] S.V. Buer, J.O. Strandhagen, F.T.S. Chan, *The Link Between Industry 4.0 and Lean Manufacturing: Mapping Current Research and Establishing a Research Agenda*, "International Journal of Production Research" 2018, vol. 56(8), pp. 2924–2940.

Source: own elaboration based on G. Büchi, M. Cugno, R. Castagnoli, *Smart factory performance and Industry 4.0*, "Technological Forecasting & Social Change" 2020, no. 150, 119790; M. Javaid, A. Haleem, R. Vaishya, S. Bahl, R. Suman, A. Vaish, *Industry 4.0 technologies and their applications in fighting COVID-19 pandemic*, "Diabetes & Metabolic Syndrome: Clinical Research & Reviews" 2020, vol. 14(4), pp. 419–422; V. Alcácer, V. Cruz-Machado, *Scanning the Industry 4.0: A Literature Review on Technologies for Manufacturing Systems*, "Engineering Science and Technology, an International Journal" 2019, vol. 22(3), pp. 899–919; D. Ivanov, A. Dolgui, *A digital supply chain twin for managing the disruption risks and resilience in the era of Industry 4.0*, "Production Planning & Control" 2021, vol. 32(9), pp. 775–788; M. Piccarozzi, B. Aquilani, C. Gatti, *Industry 4.0 in Management Studies: A Systematic Literature Review*, "Sustainability" 2018, vol. 10(10), 3821; D. Horváth, R.Zs. Szabó, *Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities?*, "Technological Forecasting & Social Change" 2019, no. 146, pp. 119–132; Ch. Bai, P. Dallasega, G. Orzes, J. Sarakis, *Industry 4.0 technologies assessment: A sustainability perspective*, "International Journal of Production Economics" 2020, no. 229, 107776; D. Ivanov, Ch. Tang, A. Dolgui, D. Battini, A. Das, *Researchers' perspectives on Industry 4.0: multi-disciplinary analysis and opportunities for operations management*, "International Journal of Production Research" 2021, vol. 59(7), pp. 2055–2078; F. Rosin, P. Forget, S. Lamouri, R. Pellerin, *Impacts of Industry 4.0 technologies on Lean principles*, "International Journal of Production Research" 2020, vol. 58(6), pp. 1644–1661; V. Pilloni, *How Data Will Transform Industrial Processes: Crowdsensing, Crowdsourcing and Big Data as Pillars of Industry 4.0*, "Future Internet" 2018, vol. 10(3), 24.

The age of Industry 4.0 forces new technological solutions and requirements for organisations connected with building the new evolutions' fundamentals. First of all, the new technological solutions must be implemented taking into account Virtual and Augmented Reality[16] (support for the engineers during the design and service work as well as the limitations of the costs of the training for the new employees), Neural Networks[17] (set of the algorithms recreating the behaviour of the human brain designed to recognise the patterns), Machine-to-Machine Communication[18] (direct communications between machines). Secondly, digital enhancement must be applied based on Cybersecurity[19] (strategy connected with the appropriate methodology for designing industrial production systems and implementing the security measures to limit external and internal cybernetic threats within the organisation). No less important are Cyber-Physical Systems[20] (integration of the production systems with IT and business platform, development of the cyber-physical systems for connecting the mechatronic, electronic as well, as communication systems via adapted software) supported by Digital Twin[21] (software which enables the creation of virtual representations of the physical systems simulations connected with the end-to-end product life cycle management). Further requirements are connected with the innovative methods of collecting data, especially Big Data Analytics[22] (analysis of significant and diverse data sets used for the optimisation of the processes, detection of irregularities and interpretation of production data) and Cloud Computing[23] (distributed computational structure which enables remote storage and processing of the data, virtualisation of the resources and scaling ability of the systems). Essential support for these technologies is

16 H. Liu, L. Wang, *An AR-based Worker Support System for Human-Robot Collaboration*, "Procedia Manufacturing" 2017, no. 11, pp. 22–30.

17 A. Maciąg, R. Pietroń, S. Kukla, *Prognozowanie i symulacja w przedsiębiorstwie*, Polskie Wydawnictwo Ekonomiczne, Warszawa 2013.

18 O.A. Amodu, M. Othman, *Machine-to-Machine Communication: An Overview of Opportunities*, "Computer Networks" 2018, no. 145, pp. 255–276.

19 J. Jang-Jaccard, S. Nepal, *A survey of emerging threats in cybersecurity*, "Journal of Computer and System Sciences" 2014, vol. 80(5), pp. 973–993.

20 K.-D. Kim, P.R. Kumar, *Cyber-Physical Systems: A Perspective at the Centennial*, "Proceedings of the IEEE" 2012, no. 100, pp. 1287–1308; S. Saniuk, S. Grabowska, *The Concept of Cyber-Physical Networks of Small and Medium Enterprises under Personalized Manufacturing*, "Energies" 2021, vol. 14(17), pp. 1–19; S. Saniuk, *Cyber-fizyczne sieci produkcyjne małych i średnich przedsiębiorstw zorientowane na spersonalizowaną produkcję*, [in:] R. Knosala (ed.), *Inżynieria zarządzania: cyfryzacja produkcji. Aktualności badawcze 4*, Polskie Wydawnictwo Ekonomiczne, Warszawa 2022, pp. 63–72.

21 Q. Qi, F. Tao, *Digital Twin and Big Data Towards Smart Manufacturing and Industry 4.0: 360 Degree Comparison*, "IEEE Access" 2018, no. 6, pp. 3585–3593.

22 A. Gandomi, M. Haider, *Beyond the hype: Big data concepts, methods, and analytics*, "International Journal of Information Management" 2015, vol. 35(2), pp. 137–144.

23 Q. Zhang, L. Cheng, R. Boutaba, *Cloud computing: state-of-the-art and research challenges*, "Journal of Internet Services and Applications" 2010, no. 1, pp. 7–18.

the innovative methods of transferring collected data such as the Internet of Things[24] (communication with distributed sensors, devices and other network elements, implementation of the technical and business solutions based on Internet technologies), Internet of Services (the set of the software applications used for the development of the services and digital platforms connected with the technological development of organisation). One of the most significant elements is introducing the intelligent work environment associated with machines, processes, systems, products, production, and supply chain factories[25]. In the productions, the most significant role plays Robotisation[26] (a new generation of application-flexible robots solutions that can cooperate with people without factory protective fences, the self-ability to the adoption and implementation) based on Artificial Intelligence[27] (a set of technologies that enable machines to learn and solve complex problems, implement advanced decision algorithms and learning systems). Significant technologies from the production point of view are also Additive Manufacturing[28] (a wide range of rapid prototyping of elements and production parts with characteristic or unusual shapes also functions, low as well as medium volume production from plastics, resins, metals) and Radio-frequency Identification[29] (data storage and communication with production as well as warehouse management systems, the ability to create intelligent products that communicate directly with machines). Other elements supporting manufacturing in the age of Industry 4.0 are Blockchain[30] (technology which collects information about transactions by creating distracted registers, the possibility to conclude intelligent contracts between entities without the existence of a guarantor in the form of a third organisation or

24 D. Miorandi, S. Sicari, F. De Pellegrini, I. Chlemtac, *Internet of things: Vision, applications and research challenges*, "Ad Hoc Networks" 2012, vol. 10(7), pp. 1497–1516.

25 D. Ivanov, A. Dolgui, B. Sokolov, F. Werner, M. Ivanova, *A dynamic model and an algorithm for short-term supply chain scheduling in the smart factory industry 4.0*, "International Journal of Production Research" 2015, vol. 54(2), pp. 386–402.

26 Z. Cséfalvay, *Robotization in Central and Eastern Europe: catching up or dependence?*, "European Planning Studies" 2020, vol. 28(8), pp. 1534–1553.

27 Y. Duan, J. Edwards, Y. Dwivedi, *Artificial intelligence for decision making in the era of Big Data – evolution, challenges and research agenda*, "International Journal of Information Management" 2019, no. 48, pp. 63–71.

28 H. Gaub, *Customization of mass-produced parts by combining injection molding and additive manufacturing with Industry 4.0 technologies*, "Reinforced Plastics" 2016, vol. 60(6), pp. 401–404.

29 Y. Xiao, S. Yu, K. Wu, Q. Ni, Ch. Janecek, J. Nordstad, *Radio frequency identification: technologies, applications, and research issues*, "Wireless Communications and Mobile Computing" 2007, vol. 7(4), pp. 457–472.

30 Nir Kshetri, *Blockchain's Roles in Meeting Key Supply Chain Management Objectives*, "International Journal of Information Management" 2018, no. 39, pp. 80–89.

institution) and Geolocalisation[31] (the system used in logistics and management of distributed assets, vehicle fleet or remote teams of employees based on the determination of the geographical location using GPS or IP address). The significant elements that are changing the approach to post-production activities are Mass Customisation[32] (change of the production attitude from the mass production defined by the manufacturer to the mass personalisation defined by the customer's requirements with simultaneous limitation of the overall costs and production time) and Value Chain Transformation[33] (evolution of the Michael Porter concept which introduces the integration in two dimensions. Vertical is matched with integrating production processes within the organisation in R&D, purchasing, logistics and marketing[34]. Comprehensive management of product life and assets becomes possible. Horizontal is connected with integrating with the organisation's external contractors by monitoring the intelligent systems of service and logistics[35]. The overall quality of planning the production process increases by introducing more transparent network communication)[36]. As a summary of this section, Table 1.2 presents the mentioned Industry 4.0 enabling technologies with key benefits and examples of their results.

With the advent of Industry 4.0, the new technological, social, cultural and environmental requirements had to be changed, considering the upcoming changes' consequences.

31 R. Yokota, Y. Hawai, K. Tsuchiya, D. Imoto, M. Hirabayashi, N. Akiba, H. Kakuda, K. Tanabe, M. Honma, K. Kurosawa, *A revisited visual-based geolocalization framework for forensic investigation support tools*, "Forensic Science International: Digital Investigation" 2020, no. 35, 301088.

32 S. Jack Hu, *Evolving Paradigms of Manufacturing: From Mass Production to Mass Customization and Personalization*, "Procedia CIRP" 2013, no. 7, pp. 3–8.

33 W. Reinartz, N. Wiegand, M. Imschloss, *The impact of digital transformation on the retailing value chain*, "International Journal of Research in Marketing" 2019, vol. 36(3), pp. 350–366.

34 A. Adamik, M. Nowicki, K. Szymańska, *Openness to co-creation as a method of reducing the complexity of the environment and dynamizing companies' competitive advantages*, "Management & Marketing. Challenges for the Knowledge Society" 2018, vol. 13(2), pp. 880–896.

35 A. Adamik, M. Nowicki, *Co-creating value in the era of Industry 4.0*, "Entrepreneurship & Management" 2018, vol. 19(6.1), pp. 23–39.

36 Z. Piątek, *Od Industry 4.0 do Smart Factory: technologie i zmiany organizacyjne*, 2018, http://przemysl-40.pl/index.php/2018/02/01/od-industry-4-0-do-smart-factory-czesc-2/ (accessed: 20.04.2020).

Table 1.2. Key benefits and its results of Industry 4.0 enabling technologies

Industry 4.0 enabling technologies	Key benefits	Examples of results
– Internet of Things – Internet of Services – Cyber-Physical Systems – Information Network – Software Systems – Cloud Computing – Big Data Analytics – M2M Communication – Cybersecurity – Virtual Reality – Augmented Reality – Neural Networks – Digital Twin – Artificial Intelligence – Blockchain – RFID – Geolocalisation – Additive Manufacturing – Robotisation	Meeting individual customer demands	Including individual customer-specific criteria in the process of production
		Rapid transferring of customer requirements into production processes
		Enabling a high level of flexibility
		Enabling last-minute changes into the production process
	Flexible and agile engineering and manufacturing	Dynamic and flexible configuration of various elements of business processes
		Creation of agile engineering and manufacturing processes
		On-time verification of design decisions and quick incorporation of decisions into engineering and production processes
		Improved responsiveness and decision making
	Improved information sharing and decision making	Easy access to real-time information and effective cooperation between different machinery and manufacturing systems
		Improved performance and production quality
		Improved product development
	Improved integration and collaboration	Improved information sharing and collaboration
		Monitoring operations from any location
		Enabling proactive approach towards problem-solving
	Improved resource productivity	Continuous optimisation of manufacturing processes and production systems
		Creating cost-effective measurement systems and performance management tools
		Automation of environmental control tools
	Mass customisation	Individualisation manufacturing processes
		Production of highly customised products at low volume
		Generation of high quality and highly customised products

Source: own elaboration as cited in H. Fatorachian, H. Kazemi, *A critical investigation of Industry 4.0 in manufacturing: theoretical operationalization framework*, "Production Planning and Control" 2018, vol. 29(8), pp. 633–644 based on: W.W.H. Kagermann, J. Helbig, W. Wahlster, *Recommendations…*; P. Helo, Y. Hao, *Cloud manufacturing system for sheet metal processing*, "Production Planning & Control" 2017, vol. 28(6–8), pp. 524–537; D.M. Upton, *Flexibility as process mobility: The management of plant capabilities for quick response manufacturing*, "Journal of Operations Management" 1995, vol. 12(3–4), pp. 205–224; C. Oberg, G. Graham, *How smart cities will change supply chain management: a technical viewpoint*, "Production Planning & Control" 2016, vol. 27(6), pp. 529–538; E. Abele, A. Wörn, J. Fleischer, J. Wieser, *Mechanical module interfaces for reconfigurable machine tools*, "Production Engineering" 2007, vol. 1(4), pp. 421–428; B. Hu, D. Kostamis, *Managing supply disruptions when sourcing from reliable and unreliable suppliers*, "Production and Operations Management" 2015, vol. 24(5), pp. 808–820; Y.J. Chen, M. Deng, *Information Sharing in a Manufacturer – Supplier Relationship: Suppliers' Incentive and Production Efficiency*, "Production and Operations Management" 2015, vol. 24(4), pp. 619–633; M. Lang, P. Deflorin, H. Dietl, E. Lucas, *The impact of complexity on knowledge transfer in manufacturing networks*, "Production and Operations Management" 2014, vol. 23(11), pp. 1886–1898.

Today's world is developing at a breakneck pace, constantly increasing new technologies to improve and optimise production and everyday life. Since the dawn of time, experts in various fields have asked themselves how the world will look. Development of the Internet, intelligent systems, and their applications with humanity's cooperation, new and unlimited possibilities have started to be seen for the rapid growth of all industries. The constant way to innovate and increase workers' productivity and production has created a new perspective on the competitiveness between organisations in critical global markets. At the same time, the classical business model has started to change. Experts from various industry branches and education began to fully transform existing business models or create new ones adapted to a rapidly changing reality. The biggest problem was enhancing customer requirements for the offered products and versatility combined with the ordered goods' functionality. These dependencies forced experts to create new business and economic realities adapted to the latest trends and customers' requirements. Finally, the German concept, Industry 4.0, was prepared[37].

Industry 4.0 requires improving production systems to solve complex problems and quickly adapt products to individual customers' preferences while reducing production costs. Tools that enable implementing the above assumptions are advanced IT systems based on a fast flow of information through internet networks and large databases collecting data at each production stage. Generally, the term the age of Industry 4.0 is connected with unifying the real world of production machines with the virtual world's overall concept matched with the internet and information technologies[38]. People, machines, and implemented IT systems automatically exchange the information connected with the production and organisation of the manufacturing processes, considering the organisation's whole environment and the connection with the international branches via cloud computing. Industry 4.0 includes the appropriate process activities from the first signs of the order, producing the customers' delivery components[39].

The whole environment of Industry 4.0 allows gathering access to a suitable set of information related to the stages of the production process all the time from all over the world. This dependence, called mass customisation, allows the identification, limited production and design of personalised products for demanding customers based on the web connection and the interconnected data flow. It gives the opportunity to significantly increase the elasticity and decrease the overall cost of the manufactured products.

37 D. Plinta, *New Information Technologies in production enterprises*, [in:] *idem* (ed.), *Advanced Industrial Engineering Industry 4.0*, Wydawnictwo Fundacji Centrum Nowych Technologii, Bielsko-Biała 2016, p. 8.

38 L. Adolph, T. Anlahr, H. Bedenbender, *German Standardization Roadmap: Industry 4.0. Version 2*, DIN e. V., Berlin 2016.

39 *Intelligent World 2030*, https://www-file.huawei.com/-/media/corp2020/pdf/giv/intelligent_world_2030_en.pdf (accessed: 28.11.2022).

Nevertheless, the increased innovation potential connected with the IT world allows organisations to secure the knowledge related to research and development by creating competitiveness. Production tools can modify their operations, adapting to the new range of tasks by introducing the appropriate machine program commands. This feature can also limit the production time because all unnecessary functions are excluded, so the process's efficiency still increases to fulfil low-volume personalised orders[40]. Innovative production systems can be evolved by developing existing and new technology implementation methods. The connection between the current way of organising and preparing the production must be connected with the latest concepts of Industry 4.0. This solution can be achieved by the introduction of the reduction of production cycles, minimalisation of the level of suppliers with more effective logistics, innovative ideas in the field of production as well as the business departments based on Lean Production[41], Just in Time, Total Quality Management[42] and Digital Factory Technologies[43]. Adaptation of machines and people is one of the most significant elements of modifying production lines according to the age of Industry 4.0[44]. All expendable movements are almost minimal, considering the lack of time.

Due to the specific requirements of Industry 4.0, more social and economic issues need to be SMART. Defining the concept of SMART, the terms intelligence and smartness should be introduced.

The concept of smartness refers to agility and resilience based on adopting emerging technologies[45] related to interconnectedness, efficiency, transparency, effectiveness, sustainability and collaboration[46]. Smartness is a multi-dimensional concept with several dimensions, such as sustainability equality, innovation integration, integration, technology savviness innovation, creativity, equality, entrepreneurialism, and citizen centricity[47].

40 Z. Piątek, *Czym jest Przemysł 4.0? – część 1*, 2017, http://przemysl-40.pl/index.php/2017/03/22/czym-jest-przemysl-4-0/ (accessed: 20.04.2020).

41 J. Davis, T. Edgar, J. Porter, J. Bernaden, M. Sarli, *Smart manufacturing, manufacturing intelligence and demand-dynamic performance*, "Computers & Chemical Engineering" 2012, no. 47, pp. 145–156.

42 J. Lewandowski, B. Skołud, D. Plinta, *Organizacja systemów produkcyjnych*, Polskie Wydawnictwo Ekonomiczne, Warszawa 2014.

43 D. Plinta, *New Information Technologies…*, pp. 7–20.

44 A. Adamik, *Inteligencja organizacji w erze IR 4.0*, "Studia i Prace Kolegium Zarządzania i Finansów" 2019, no. 161, pp. 81–97.

45 J.R. Gil-Garcia, N. Helbig, A. Ojo, *Being smart: Emerging technologies and innovation in the public sector*, "Government Information Quarterly" 2014, no. 31, pp. 11–18.

46 T. Nam, T.A. Pardo, *The changing face of a city government: A case study of Philly311*, "Government Information Quarterly" 2014, no. 31, pp. 1–9.

47 K. Axelsson, M. Granath, *Stakeholders' stake and relation to smartness in smart city development: Insights from a Swedish city planning project*, "Government Information Quarterly" 2018, vol. 35(4), pp. 693–702.

With the growth of technological possibilities, intelligence has evolved, and it is used in all possible solutions in the technological and social spheres. Being intelligent has become one of the main features of the organisation model. However, one must be very careful about the proper context of the word intelligence because of its multidimensionality concerning the personal, organisational, technological and informational levels[48]. SMART can be built at various levels, in many functional areas and for the whole organisation. When we analyse the issue at a general level, we discuss the SMART organisation, described in more detail in section 1.2. However, different organisational intelligence[49] types emerge when we analyse the SMART organisation at a more specific level.

Turning to the organisational level, it is worth quoting the definition created by Borowiecki and Kwieciński, which states that an organisation's intelligence can be practised as a result of a set of actions that trigger all the skills of people to be measured (e.g., those that result from the level of education). Those that can be started as a result of these actions and that is usually not perceived and appreciated. Therefore, the aim is to achieve a synergistic effect from organised human activities that benefit the maximum[50]. An organisation's intelligence consists of human and machine intelligence, increasing competitive strength[51]. On the other hand, according to Albrecht, it is a mental capacity associated with performing tasks and essential activities. According to him, organisational intelligence consists of seven components: strategic vision, shared destiny, willingness to change, heart, alignment, application of knowledge and performance pressures[52].

Technological intelligence and business intelligence are also significant from an organisational perspective. According to Fourati-Jamoussi, Niamba, and Duquennoy, "technological intelligence is to follow a technical and scientific domain in time and to monitor developments"[53]. Nevertheless, considering the technical terms in Industry 4.0, higher levels of intelligence are being used in industrial processes, and it is matched with the communication with and between objects. According to Pilloni, objects with

48 A. Adamik, *Inteligencja organizacji…*

49 *Eadem*, *Change and Relational Strategies: Through an Organizational Intelligence Lens*, [in:] K.J. Klimczak, Y. Shachmurove (eds.), *Organizational Change and Relational Resources*, Routledge, New York 2021, pp. 47–78.

50 R. Borowiecki, M. Kwieciński, *Monitorowanie otoczenia: przepływ i bezpieczeństwo informacji. W stronę inteligencji przedsiębiorstwa*, Kantor Wydawniczy Zakamycze, Kraków 2003, p. 92.

51 M.A. Bahrami, M.M. Kiani, R. Montazeralfaraj, H.F. Zadeh, M.M. Zadeh, *The Mediating Role of Organizational Learning in the Relationship of Organizational Intelligence and Organizational Agility*, "Osong Public Health and Research Perspectives" 2016, vol. 7(3), pp. 190–196.

52 K. Albrecht, *The power of minds at work: Organizational intelligence in action*, Karl Albrecht International, California 2008.

53 F. Fourati-Jamoussi, C.N. Niamba, J. Duquennoy, *An evaluation of competitive and technological intelligence tools: A cluster analysis of users' perceptions*, "Journal of Intelligence Studies in Business" 2018, vol. 8(1), p. 8.

lower efficiency can freely use the resources possessed by more intelligent objects, regardless of their location. An example of such an object would be all kinds of sensors. On the other hand, direct communication can be used by objects whose status we consider intelligent to enhance their capabilities by gathering non-poor information collected and stored by distributed objects regardless of whether objective or subjective[54]. However, when considering the concept of business intelligence, the following definition is provided by Mariani et al., "BI comprises all the activities, applications and technologies needed for the collection, analysis and visualisation of business data to support both operative and strategic decision-making"[55], while Dedić and Stainer suggest that "BI as a term which includes the strategies, processes, applications, data, products, technologies and technical architectures used to support the collection, analysis, presentation and dissemination of business information"[56]. It is also worth quoting another definition given by Chang, which states that "The term 'Business Intelligence' refers to a set of methods, processes, architectures and technologies that can process and transform collected datasets into meaningful and useful information for business purposes, and often used in business-critical servers, applications and services"[57].

According to the presented description of intelligence, as the author defined it, the concept of SMART is one of the critical elements of creating a new vision of industry based on the assumptions of the age of Industry 4.0. This term generally refers to aspirations and opportunities entirely dependent on the individual perspective based on the conditions, environment, culture and values represented by a man. The SMART concept also refers to private spheres of life, such as the living environment, which has to improve as awareness of the latest technologies increases. Being SMART is about being intelligent, aspirational and goal-oriented in implementing innovative solutions to achieve the desired future. One of the main building blocks is the SMART Future[58], which consists of innovations that help support intelligent solutions to complex problems that secure the human environment[59]. SMART future is not only the latest

54 V. Pilloni, *How Data Will Transform…*

55 M. Mariani, R. Baggio, M. Fuchs, W. Höepken, *Business intelligence and big data in hospitality and tourism: a systematic literature review*, "International Journal of Contemporary Hospitality Management" 2018, vol. 30(12), p. 3516.

56 N. Dedić, C. Stanier, *Measuring the success of changes to existing business intelligence solutions to improve business intelligence reporting*, "Lecture Notes in Business Information Processing", vol. 268, Springer International Publishing, Cham 2016, p. 226.

57 V. Chang, *The Business Intelligence as a Service in the Cloud*, "Future Generation Computer Systems" 2014, no. 37, p. 513.

58 A. Adamik, *SMEs on the Way to the Smart World of Industry 4.0*, "Eurasian Studies in Business and Economics" 2020, vol. 12(2), pp. 139–156.

59 N. Streitz, *Citizen-centered design for human and sociable hybrid cities*, [in:] I. Theona, D. Charitos (eds.), *Hybrid City 2015 – Data to the People. Proc. of the Third International Biannual Conference*, University of Athens, Athens 2015, pp. 17–20.

technological innovations based on gadgets, accessories and complex communication networks but equity and social responsibility, transparency of legal rules, and sharing visions and goals with others without restrictions[60]. It would enable high-speed data exchange between research centres around the world. The most significant thing is creating a shared vision of the future based on people who will remember to protect the heritage and human environment despite the rapid development of machines and artificial intelligence. Then we should mention the SMART world[61], which will slowly become our everyday life. Introducing new communication and digitisation methods will create a new space based on integrated cyber-physical-social thinking. The primary assumption of the SMART world[62] is to create a hyperspace containing all possible connections and the development of intelligence of physical perception, social correlation and cognitive thinking concerning all aspects of everyday life concerning the latest technological solutions[63] which the main element is the SMART Environment presented in Table 1.3.

Table 1.3. SMART Environment components

SMART Environment components	Functions and elements in the age of Industry 4.0
SMART Country (SMART Region, SMART Agriculture, SMART Specialisations, SMART City)	Advanced IT connectivity
	Active participation of citizens in improving the city
	Public access to information
	Opportunity for development
	Sustainable resource management
SMART People (SMART Employees, SMART Engineers)	Level of qualification
	Social and ethic plurality
	Flexibility, creativity and open-mindedness
	Participation in public live
	Affinity to lifelong learning

60 J. Canton, *Future smart: Managing the game-changing trends that will transform your world*, Da Capo Press, Boston 2015.

61 Ch. Zhu, V.C.M. Leung, L. Shu, C.H. Ngai, *Green Internet of Things for Smart World*, "IEEE" 2015, no. 3, pp. 2151–2162.

62 A. Adamik, *SMEs on the Way…*

63 J. Ma, L.T. Yang, B.O. Apduhan, R. Huang, L. Barolli, M. Takizawa, *Towards a smart world and ubiquitous intelligence: A walkthrough from smart things to smart hyperspaces and UbicKids*, "International Journal of Pervasive Computing and Communications" 2005, vol. 1(1), pp. 53–68; H. Liu, H. Liu, H. Ning, Q. Mu, Y. Zheng, J. Zeng, L.T. Yang, R. Huang, J. Ma, *A Review of smart world*, "Future Generation Computer Systems" 2017, no. 96, pp. 678–691; H. Ning, H. Liu, *Cyber-physical-social-thinking space based science and technology framework for the internet of things*, "Science China Information Sciences" 2015, vol. 58(3), pp. 1–19.

SMART Environment components	Functions and elements in the age of Industry 4.0
SMART Governments (SMART Communities)	Participation in decision-making
	Public and social services
	Political strategies
	Political perspectives
	Improved fiscal sustainability
SMART Mobility (SMART Infrastructure, SMART Transport)	Local accessibility
	National and International accessibility
	Availability of ICT-infrastructure
	Sustainable, innovative and safe transport systems
	Well-developed navigation systems
SMART Living (SMART Healthcare, SMART Education, SMART Houses)	Cultural facilities
	Great health conditions
	Increased housing quality
	Developmental education facilities
	Social cohesion
SMART Industry (SMART Technologies, SMART Services, SMART Grid, SMART Manufacturing, SMART Factory)	Automation
	Process digital control
	Cutting edge technologies
	Artificial intelligence
	Highly educated workforce
SMART Privacy	Cybersecurity
	Protection of confidential data
	Encryption of data
	Staged authentication
	Continuous surveillance of the network
SMART Organisation (SMART Customers, SMART Suppliers, SMART Competitors, SMART Employees)	Flexibility on labour market
	Ability to transform
	Open culture
	Open resources
	Open knowledge

Source: own elaboration based on M. Batty, K.W. Axhausen, F. Giannotti, A. Pozdnoukhov, A. Bazzani, M. Wachowicz, G. Ouzounis, Y. Portugali, *Smart cities of the future*, "The European Physical Journal Special Topics" 2012, no. 214, pp. 481–518; A. Adamik, *SMEs on the Way…*; A. Adamik, M. Nowicki, A. Puksas, *Energy Oriented Concepts and Other SMART WORLD Trends as Game Changers of Co-Production-Reality or Future?*, "Energies" 2022, vol. 15(11), 4112; A. Adamik, V.M. Ghinea, M. Ghinea, M. Nowicki, *Mapping the maturity of SMART WORLD trends as a tool for developing business excellence and reducing organizational complexity*, "Management & Marketing. Challenges for the Knowledge Society" 2022, vol. 17(2), pp. 193–219.

In Industry 4.0, with the rapid growth of technological and management capabilities, it has been decided to introduce new business models[64] directly based on digitisation, enabling high-speed data exchange between every organisation branch. Each organisation was forced to implement new innovative solutions both on the management and technological level. When we hear about the age of Industry 4.0, we, first of all, think only about technological novelties. However, we must remember to change the organisation's strategy concerning operations and relations between the producer and the customer. The main processes introduced in the business area are Mass Customization & Mass Personalization, New Manufacturing Model & Customer Development, Integration of the Product Lifecycle, Value Chain Transformation and New Business Models. It is also worth mentioning that Industry 4.0 places a great deal of emphasis on R&D activities, making it possible to test implemented innovative actions in actual conditions. There is also an upward trend in R&D spending in all branches of industry.

Mass Customisation[65] has been created with the ever-changing production model related to customer requirements towards personalising purchased products. Currently, most goods are produced in one version, which the customer can choose, e.g. colour, size and price range. However, the current market situation requires manufacturers to work closely with customers. With each subsequent version of the product, the customer's demands increase. Everyone wants to get a customised product, usually personalised. This solution has a tremendous impact on the mass production paradigm, where the customer once depended on the manufacturer's initiative. The growing demands shape a new philosophy of production directly connected with close cooperation with the customer. The price range of the offered product plays a significant role in this process. If the product is expensive, exclusive personalisation for a specific customer is now standard.

Based on a new approach to the customer, a New Manufacturing Model has been introduced, which, by using the Internet as a telecommunication medium, enables direct contact with the customer, who updates the requirements for the ordered product on an ongoing basis. It also allows preparation feedback for the manufacturer improving products in the future for a specific customer. Customer Development is the relationship between the manufacturer and the customer[66]. This process requires

64 J. Yun, D. Won, E. Jeong, K. Park, J. Yang, J. Park, *The relationship between technology, business model, and market in autonomous car and intelligent robot industries*, "Technological Forecasting and Social Change" 2016, no. 103, pp. 142–155.

65 P. Zawadzki, K. Żywicki, *Smart product design and production control for effective mass customization in the Industry 4.0 concept*, "Management and Production Engineering Review" 2016, vol. 7(3), pp. 105–112.

66 Ch. Fuchs, M. Schreier, *Customer Empowerment in New Product Development*, "Journal of Product Innovation Management" 2011, vol. 28(1), pp. 17–32.

a customer-centric organisation. An essential element is analysing data obtained from the customer, showing the relative path of product development. Many organisations provide pre-release products to selected users to receive current functionalities and possibilities. The manufacturer can reduce the deficiencies and non-working options in the final product officially released on the market through close cooperation with the customer. It is also a widespread practice to provide the customer with an interface for data collection and direct contact to obtain new fault data in real-time, regardless of the time zone.

Also worth mentioning is the Value Chain Transformation[67], which had to be rebuilt based on adapting Porter's classic model to the latest digital transformation developments. The new approach specifies the division on the vertical and horizontal dimensions. The vertical one focuses on the prioritisation of values within the organisation. Insight into all production process data opens up new opportunities to integrate all modules defining the entire process. From R&D, interdisciplinary product and asset life management can be applied through purchasing, manufacturing, logistics and marketing. Establishing new values for the individual stages increases productivity and checks which processes are most relevant. It also allows for a more efficient exchange of data concerning the entire process, specifying the appropriate control points necessary to continue the process with maximum efficiency. Categorisation allows changing the load distribution of production machines to perform priority actions required for any operation in the first place. On the other hand, the levels focus on cooperation with external partners based on intelligent supply, logistics systems, and tracking components of a given product. This solution enables high-speed data exchange between manufacturers and suppliers of individual raw materials.

The Integration of the Product Lifecycle[68] is based on product traceability using the latest monitoring systems that work with the latest communication media. The newest technologies allow for real-time tracking of the product lifecycle, gathering information on the use and performance of manufactured goods used by customers. Product Lifecycle starts with analysing the market, potential customers, suppliers and business partners. In subsequent stages, requirements are defined. Then a general concept is prepared and transformed into a prototype by engineers and designers. The production process and the selection of components from external contractors are ready. Four main monitoring areas are needed to create the whole scheme of Product Lifecycle Management: People, Data, Application and Process. Everyone is in contact with the production process, and every customer who buys a product or service is monitored, starting with people. Data from both the production areas showing the efficiency

67 W. Reinartz, N. Wiegand, M. Imschloss, *The impact of digital transformation…*

68 M.J. Yoo, C. Grozel, D. Kiritsis, *Closed-Loop Lifecycle Management of Service and Product in the Internet of Things: Semantic Framework for Knowledge Integration*, "Sensors" 2016, vol. 16(7), 1053.

and effectiveness of the production line are analysed. On the other hand, the information obtained from customers concerning use is analysed. This system reduces errors to a minimum, reacts quickly, and increases customer satisfaction in the future. The application of the offered product service is also checked due to the industries in which it is used. This solution allows the preparation of personalised or specialised versions of products for specific customers based on individual preferences in the future. The last area is the process itself, in which the whole course of the product is monitored from the moment of design until the customer receives it. Tracking the process allows for modifications at each design stage, production or consumer. All Integration of Product Lifecycle Management elements is designed to collect information from all areas to better adapt the offered products or services to current and new customers based on the latest available technologies and communication channels used in the age of Industry 4.0.

New business models are the foundation for introducing dynamic management based on the assumptions of the age of Industry 4.0. The digitalisation of the production process requires changes in the structure of the use of machines and software and the management approach by implementing new business models based on e-business principles. Offering a product as a service is a perfect example. This solution involves introducing support for the use of a given product. Clouds can be an excellent example, wherein we can expand the base product with additional functions, depending on the needs, more specialised or personalised. Another element is the service support for the used modules consisting of updating the software to the latest version and standard technical support in case of failure or configuration problems. Description of new business models according to the principles of the age of Industry 4.0 can be found in: Osterwalder and Pine[69], Gorevaya and Khayrullina[70], Schroeder[71], Niemczyk and Trzaska[72], Härting, Reichstein, and Schad[73], Frank et al.[74]

69 A. Osterwalder, I. Pine, *Building business models*, Alpina Publisher Series Skolkovo, Moscow 2013.

70 E. Gorevaya, M. Khayrullina, *Evolution of business models: past and present trends*, "Procedia Economics and Finance" 2015, no. 27, pp. 344–350.

71 R. Schroeder, *Big data business models: Challenges and opportunities*, "Cogent Social Sciences" 2016, vol. 2(1), 1166924.

72 J. Niemczyk, R. Trzaska, *Klasyfikacja modeli biznesowych w Industry 4.0*, [in:] S. Gregorczyk, G. Urbanek (eds.), *Zarządzanie strategiczne w dobie cyfrowej gospodarki sieciowej*, Wydawnictwo Uniwersytetu Łódzkiego, Łódź 2020, pp. 271–286.

73 R.-Ch. Härting, Ch. Reichstein, M. Schad, *Potentials of Digital Business Models – Empirical investigation of data driven impacts in industry*, "Procedia Computer Science" 2018, no. 126, pp. 1495–1506.

74 A.J. Frank, G.H.S. Mendes, N.F. Ayala, A. Ghezzi, *Servitization and Industry 4.0 convergence in the digital transformation of product firms: A business model innovation perspective*, "Technological Forecasting and Social Change" 2019, no. 141, pp. 341–351.

The requirements of the age of Industry 4.0 presented in Table 1.4 in the following areas: technology, strategy, structural solutions and social attitudes and competencies are connected with the necessity of transformation of organisations both in the context of changes directed at the implementation of innovative solutions combined with digitalisation and new technologies, as well as changes in management methods. To meet these requirements and be able to exist and stay on the market, organisations are forced to adapt constantly to the new reality, which often requires changes in the strategy of operation and the business model. These changes determine the emergence of a new type of organisation, considered SMART, described in more detail in section 1.2. These organisations use technologies that allow new manufacturing methods and production and information management. These changes aim to improve the organisation's functioning regarding process optimisation, flexibility, rapid response to environmental changes, quality, efficiency, and effectiveness.

Table 1.4. Summaries of requirements of the age of Industry 4.0

Key requirements areas of the age of Industry 4.0			
Technologies	**Strategies**	**Structural solutions**	**Attitudes and social competences**
Information and Communication Technologies: Internet of Things, Internet of Services, Cyber-Physical Systems, Information Network, Software Systems, Cloud Computing, Big Data Analytics, M2M Communication, Cybersecurity	**Key resources:** qualified employees, knowledge, relationships, dynamic capabilities, emerging technology, finance, equipment and infrastructure	**Leading solutions:** interconnection, decentralised decisions, information transparency, technical assistance, design thinking, the idea of "the connected company", knowledge and process mapping, network thinking, open business models, working in creative task and project teams, thinking and looking outside the box, unique thinking and virtualisation, open culture	**Competences:** subject-matter knowledge, continuous learning, team-working skills, ability to work in a multicultural environment, remote working skills, foreign languages knowledge, developed IT skills, ability to share knowledge, cooperation skills, communication skills, ability to think logically and analyse data, ability to act quickly and make strategic decisions, project management skills, sales and relationship skills

Key requirements areas of the age of Industry 4.0			
Technologies	**Strategies**	**Structural solutions**	**Attitudes and social competences**
Emerging technologies: Virtual Reality, Augmented Reality, Neural Networks, Digital Twin, Artificial Intelligence, Blockchain, RFID, Geolocalisation, Additive Manufacturing, Robotisation, Mass Customisation, Mass Personalisation	**Development and competitiveness strategies:** eclectic, flexible, agile, dynamic, innovative, cutting-edge, proactive	**Recommended structures:** network, matrix, hybrid, team-based	**Attitudes:** desire for continuous development, goal-orientation, openness to new experiences, creativity, flexible thinking, agility, high tolerance for uncertainty, social responsibility, intelligence, ambition, versatility, reliability, professionalism in action, awareness
	Advantage building strategies based on advantages: qualitative, diffuse, intangible, unreal, instable, synergistic		
	Functional strategies: marketing, finance, production, human resources management, research and development, logistics		
	Key solutions: agile management, co-creation, corporate social responsibility, design management, cooperation, competition, collaborative organisational learning, innovation process management, knowledge management, new technology-based business development and venturing, paradox management, partnering, simplification, sustainability, trust management, open knowledge, open innovation, open resources		

Source: own elaboration based on: A. Adamik, *Inteligencja organizacji…*

1.2. SMART organisations in the age of Industry 4.0

In the age of Industry 4.0, we mainly talk about approaching an organisation's patterns adapted to this era's requirements, i.e. SMART organisations defined in Table 1.5.

Table 1.5. SMART organisations definitions

Author	Definition
Schwaninger, 2001	SMART organisations conceive their viability more broadly than in the sense of mere survival at any price or of autopoiesis, i.e. self-reproduction. Ultimately, they adhere to the goalof development. In extreme cases, they even disband if they can no longer make a significant contribution to the larger whole.
Filos, 2006	The term "SMART organisation" was coined for organisations that are knowledge-driven, internetworked, and dynamically adaptive to new organisational forms and practices, learning as well as agile in their ability to create and exploit the opportunities offered in the digital age. SMART organisations involve more than the capability of setting up and exploiting a digital infrastructure or the ability to enter into a virtual collaboration with other partner organisations[a]. SMART organisations can enter into a virtual collaboration with other organisations. Virtual organisational forms are thus an essential characteristic of SMART organisations in the digital age[b].
Calin, Pargaru, and Neascu, 2015	SMART Organisation has instantaneous adaptability to socio-economic reality in which it operates as a primary attribute. The elements that ensure adaptability and those that define a SMART organisation are the use of information and communication technology as an optimiser for internal processes; the ongoing transformation of market data and data from related areas of activity in integrated knowledge with a high degree of persistence in terms of their usefulness; an accelerated pace of innovation on goods and services delivered. Such an organisation generates in a socio-economic environment in which it operates various effects, from a socio-professional emulation centred on competitiveness to new business models.
Adamczewski, 2016	A SMART organisation as an economic system that uses advanced ICT infrastructure in its internal organisation and also external communications is the modern core of the information society operating in business areas.
Al-Kasasbeh, Al-Kasasbeh, and Al-Faouri, 2016	The SMART organisation has a clear strategic vision, merit culture, and supportive incentives system. The SMART organisation uses the employee's collective intelligence to enhance their ability to learn and adapt to the environment[c]. The concept of the SMART organisation indicated that the organisation's ability to make SMART decisions and adapt quickly to changes in the environment is the most critical competitive advantage in the 21st century. Successful enterprises build a corporate culture that emphasizes making the right strategic decision at the right time, aligning organisational practices to support these decisions, and sustaining their outcomes[d].

Author	Definition
Adamik and Sikora-Fernandez, 2021	A SMART organisation is marked by a transitory layout and agile structure[e] learning organisation, with the capacity for creating, gaining, organizing, and sharing knowledge and using it to increase operational effectiveness, sustainable development, and competitiveness in the global market[f]. A SMART organisation bases its philosophy of operation on sustainability and knowledge management.

[a] E. Filos, E. Banahan, *Towards the Smart Organization. An Emerging Organizational Paradigm and the Contribution of the European RTD Program*, "Journal of Intelligent Manufacturing" 2001, vol. 12(2), pp. 101–119.
[b] E. Filos, *Virtuality and the Future of Organizations*, [in:] G. Putnik, M.M. Cunha (eds.), *Virtual Enterprise Integration: Technological and Organizational Perspectives*, IGI-Global, Hershey 2005,pp. 32–46.
[c] M.A. Schafer, *Organizational IQ: Characteristics Common to Smart Organizations and Applicability to the U.S. Military*, Master Thesis of Business Administration, The Naval Postgraduate School, Monterey 2009.
[d] D. Matheson, J. Matheson, *The Smart Organization: Creating Value through Strategic R&D*, Harvard Business Press, Boston 1998.
[e] I.E. Calin, I. Pargaru, M. Neascu, *The Role of Smart Organisation in Socio-Economic Environment*, "Valahian Journal of Economic Studies" 2015, vol. 6(4), pp. 41–46.
[f] P. Adamczewski, *CT solutions in intelligent organizations as challenges in a knowledge economy*, "Management" 2016, vol. 20(2), pp. 198–209.

Source: own elaboration based on: M.M. Al-Kasasbeh, S.A.M. Al-Kasasbeh, A.H. Al-Faouri, *Smart Organization Characteristics and its Impact on Social and Environmental Performance: An Empirical Study on Jordan Phosphate Mines Company*, "International Journal of Business and Management" 2016, vol. 11(8), pp. 106–115; E. Filos, *Smart Organizations in the Digital Age*, [in:] I. Mezgar (ed.), *Integration of ICT in Smart Organizations*, European Commission, Directorate-General Information Society and Media, Idea Group Publishing, Brussels 2006, pp. 1–38; A. Adamik, D. Sikora-Fernandez, *Smart Organizations as a Source of Competitiveness and Sustainable Development in the Age of Industry 4.0: Integration of Micro and Macro Perspective*, "Energies" 2021, vol. 14(6), 1572; P. Adamczewski, *CT solutions…*; M. Schwaninger, *Intelligent Organizations: An Integrative Framework*, "Systems Research and Behavioral Science" 2001, vol. 18(2), pp. 137–158; I.E. Calin, I. Pargaru, M. Neascu, *The Role of Smart Organisation in Socio-Economic Environment*, "Valahian Journal of Economic Studies" 2015, vol. 6(4), pp. 41–46.

Based on the review of definitions of a SMART organisation presented in Table 1.5 and considering the evolution of the key areas of a SMART organisation shown in Table 1.6, the key attributes of a SMART organisation can be identified.

Table 1.6. Key areas of SMART organisations

Author	Selected key areas
Senge, 1990	Personal mastery, including the need of life-long learning
	Mental models
	Building shared vision
	Team learning
	Systems thinking
Altman and Iles, 1998	Strategic management
	Systems theory
	Psychological learning theory
	Organisational context

Author	Selected key areas
Filos and Banahan, 2000	Technologies (open internet standards and technologies, middleware services, distributed organisation computing, Intelligent agents, workflow management systems, electronic commerce protocols, virtual product technologies)
	Digital economy (a network structure, self – reinforcing mechanisms, the law of abundance, pricing, virtual space, transformation, change, messiness, relationships), SMART behaviour, SMART resources (socialization, externalization, combination, internalization, human capital, structural capital, customer capital), SMART networking, SMART competencies (resource optimization, synergy creation, achieve critical mass, increase benefits)
Grudziewski and Hejduk, 2010	Information intelligence
	Technological intelligence
	Innovative intelligence
	Financial intelligence
	Marketing intelligence
	Organisational intelligence
	Social intelligence
Khan and Haleem, 2012	Partnership and collaboration
	Technology support especially (IT)
	Customer relation management / supply chain management
	Organisational structure and culture
	Change management
	Leadership and top management support
	Continuous learning and worker empowering / HRM
	Knowledge management / performance management
	Innovativeness and creativity
	Team working and concurrent engineering (CE) / integration and coordination
Borsekova and Graczyk--Kucharska, 2017	SMART working conditions
	SMART employee rotation
	SMART management
	SMART market
	SMART CSR
	SMART employees
	SMART infrastructure
	SMART services
Adamik, 2020	Open Culture
	Open Resources
	Open Knowledge

Source: own elaboration as cited in K. Borsekova, M. Graczyk-Kucharska, *Smart cities, smart organisations – similarity and differences*, 6th Central European Conference in Regional Science – CERS, Banska Bystrica 2017, based on: P.M. Senge, *The fifth discipline: The art and practice of the learning organization*, Doubleday, New York 1990; Y. Altman, P. Iles, *Learning, leadership, teams: Corporate learning and organisational change*, "Journal of Management Development" 1998, vol. 17(1), pp. 44–55; E. Filos, E. Banahan, *Towards the Smart Organization…*; W.M. Grudziewski, J.K. Hejduk, *Przedsiębiorstwo przyszłości*, Difin, Warszawa 2010; U. Khan, A. Haleem, *Smart organisations: modelling of enablers using an integrated ISM and fuzzy MICMAC approach*, "International Journal of Intelligent Enterprise" 2012, vol. 1(3/4), pp. 248–269; A. Adamik, *SMEs on the Way…*

Thanks to the above features, parameters, and capabilities, SMART organisations can be agile, adaptive, and self-organising and transform into new and better forms with a clear strategic vision and a supportive incentive system. In the business sphere, the key attributes are operational efficiency, sustainability, sustainability management, knowledge management and design thinking. Some key capabilities differentiating it from other organisations are adapting to changing situations, influencing and shaping the environment, and finding new strategic areas. Also important is the ability to make intelligent decisions and adapt quickly to environmental changes using available resources. Thus, SMART organisations can achieve a competitive advantage and advanced global competitiveness more efficiently, enabling continuous development and learning capabilities. They should also monitor the market to seek customer and market requirements for their services and technologies. It is also worth remembering information and communication technologies and emerging technologies in line with Industry 4.0 standards, which are used in production and management, introducing automation, robotisation and advanced ICT infrastructure. They also enable virtual collaboration with other organisations and effective use of digital infrastructure. An essential element of a SMART organisation is the employee[75], who should be characterised by openness, flexibility, creativity and a desire for continuous development. They need to develop their skills, individually and as part of a team, which will allow them to acquire new knowledge and increase their ability to adapt to a constantly changing environment.

Due to the latest approach to the problem of SMART organisations closely related to the age of Industry 4.0 and based on the previously described requirements of Industry 4.0 for further considerations and research the division of areas of SMART organisations according to the model of A. Adamik, presented in Table 1.7, was introduced.

75 S. Saniuk, *Wiedza i umiejętności pracowników w środowisku Przemysłu 4.0*, [in:] R. Knosala (ed.), *Inżynieria zarządzania: cyfryzacja produkcji. Aktualności badawcze 2*, Polskie Wydawnictwo Ekonomiczne, Warszawa 2020, pp. 981–988; S. Saniuk, D. Caganova, A. Saniuk, *Knowledge and Skills of Industrial Employees and Managerial Staff for the Industry 4.0 Implementation*, "Mobile Networks and Applications" 2021, vol. 26(2), pp. 1–11.

Table 1.7. Key areas of SMART organisations according to A. Adamik

SMART ORGANISATION AREAS		
OPEN CULTURE	**OPEN RESOURCES**	**OPEN KNOWLEDGE**
– Effective Leadership – Trust and Integrity – Effective Interpersonal Communications – Effective Impersonal Relations – Effective Motivation System – Effective Structure and Decision Rights – Core Values: Values, Believes, Norms – Enthusiasm – Effective Teamwork – Learning and Development Opportunities	– Operational Quality and Effectiveness – Development of Production Methods – Effective Interorganisational Cooperation – IT Infrastructure and ICT Technologies – Software Integration – Innovativeness – Economies of Scale and Operation – Digital Transformation – Virtualization of Organisational Life – Development and Implementation of New Technologies	– Effective Knowledge Management – Employee Skills Development – Interorganisational Knowledge Partnering – Effective Knowledge Sharing – Effective Process Approach to Management – Effective Competitive Strategies – Competitive Advantage – Organisational Growth and Development – Design Management – Design Thinking – Co-creation Values
HUMAN RESOURCES PLATFORM	**TECHNOLOGICAL PLATFORM**	**KNOWLEDGE PLATFORM**
SMART teams	**SMART factories**	**SMART processes**
– SMART management specialists – SMART workers – SMART partners – SMART collaborators – SMART customers – SMART suppliers – SMART competitors	– SMART technologies – SMART devices – SMART workplaces – SMART machines – SMART offices – SMART buildings – SMART structures – SMART spaces – SMART materials	– SMART cooperation – SMART partnership – SMART supply chains – SMART production – SMART logistics – SMART customers care – SMART systems (CPS) – SMART grids

Source: own elaboration based on: A. Adamik, *SMEs on the Way…*

The foundation for all these areas is the SMART management specialists team, which consists mainly of qualified leaders and managers who generate and improve new solutions based on the possibilities introduced by Industry 4.0. The consequence of the changes was also a new way of combining management with competition in the market. The SMART organisation's primary goal is to collect, analyse, and share benefits to create a coherent environment. Combining and implementing new technologies based on information processing in a much more efficient way with advanced networks enables new management processes that significantly facilitate the lives of customers and employees of the new generation of organisations. It is based on the knowledge of specialists and managers regarding concepts, principles, methods and tools concerning SMART management as perceived by Industry 4.0. They must implement planning, organising, motivating and organisational control at the level of the requirements of the age of Industry 4.0, which will be described in more detail in section 1.3.

The first area, Open Culture, is based on the definition of organisational culture. The primary and simplest definition created by Deal and Kennedy describes organisational culture as "the way we do things around here"[76]. A complete definition can be given by using the example of Schein, that organisational culture is a "dynamic phenomenon that surrounds us at all times, being constantly enacted and created by our interactions with others and shaped by leadership behavior, and a set of structures, routines, rules, and norms that guide and constrain behaviour"[77]. Further and more detailed definitions are presented by Mazur and Zaborek[78]. Today, in the age of Industry 4.0 and the SMART world, a special role of one type of organisational culture, the so-called Open Culture, is recognised. Szymańska defines the term Open Culture as "An open organisational culture is the type of culture that is characterised by the so-called open space, which refers to the willingness to change (open innovation), high tolerance of uncertainty and flexibility of operation"[79].

Components of Open Culture are effective leadership based on trust and integrity, practical interpersonal communications, and both face-to-face and through SMART communication media. It is also worth mentioning that applicable motivational systems canons sufficient decision rights. It is also worth noting the building of a value base based on beliefs and norms. Another essential component is the attitude towards work and other colleagues, characterised by an enthusiastic and meticulous approach adequate to the current situation. There would also be only achievements in the age of Industry 4.0 with good teamwork, which mobilises to develop and use learning and development opportunities at every level in the SMART organisation hierarchy.

Concerning Open Culture in the SMART organisation, we distinguish the established Human resources platform based on SMART teams, SMART workers, SMART partners, SMART customers, SMART suppliers and SMART competitors. Human resources are a collection of units that make up an organisation to no small extent.

76 T.E. Deal, A.A. Kennedy, *Corporate Cultures: The Rites and Rituals of Corporate Life*, Addison Wesley Publishing Company, Reading 1982, p. 125.

77 E.H. Schein, *Organizational Culture and Leadership*, Wiley, Hoboken 2004, p. 1.

78 J. Mazur, P. Zaborek, *Organizational Culture and Open Innovation Performance in Small and Medium-sized Enterprises (SMEs) in Poland*, "International Journal of Management and Economics" 2016, vol. 51(1), pp. 104–138.

79 K. Szymańska, *Organisational culture as a part in the development of open innovation – the perspective of small and medium-sized enterprises*, "Management" 2016, vol. 20(1), p. 150.

However, it must be assumed that people are not a resource but have a resource, i.e. a total of the qualities and qualities embodied in them that enable them to perform different roles in the organisation. Knowledge, skills, experience and attitude mainly characterise them. As far as the organisation's culture is concerned, it is worth defining the human resources management process because, in the current reality, HR departments are crucial in terms of recruitment and employee verification. According to Armstrong, human resources management is a strategic and coherent approach to managing an organisation's most valuable assets – people who individually and collectively contribute to achieving its goals[80]. According to Zając, human resources management is a set of people-related decisions and actions oriented towards the organisation's goals and meeting its employees and managers[81]. Starting from SMART workers with increasing technological capabilities, an employee must change his approach and become as universal and flexible as possible. As a summary of SMART workers, the words Oh and Park, "environmental change has brought connected and smart types of work patterns such as quite new work culture and use of technology. Thanks to the information technology-aided work process, tasks can now be allocated to workers in a more flexible manner"[82]. Then mention SMART partners. In the age of Industry 4.0, regardless of the level of cooperation, each collaborator will have to adapt to the required technological level depending on the management and impose cooperation schemes on new principles, including increased productivity and flexibility in production and management. The partner and principal of the work scope will set the organisation's cooperation level. In the age of Industry 4.0, the customer takes an active part in the product development process. He is no longer just a customer but a tester and consultant in performance and used to become a SMART customer. The customer's opinion forecasting their satisfaction with the purchased product or service becomes one of the critical elements of success in the market. Then it is worth mentioning SMART suppliers. In the age of Industry 4.0, the supplier, through extensive communication networks, presents the status and advancement of production work on an ongoing basis to determine the time and amount of components needed for a given type of work not to cause delays to the contractor. Extensive communication between the supplier and the customer allows for the introduction of necessary production changes on an ongoing basis due to the continuous updating of current processes and the advancement of work on the product. As the last component, we can recall SMART competitors. The best description of this concept will be the statement proposed by Reinartz, Wiegand, and Imschloss, "Consumers have traditionally made purchase decisions at the store

80 E. Armstrong, *Zarządzanie zasobami ludzkimi*, Oficyna Ekonomiczna, Kraków 2000.

81 Cz. Zając, *Zarządzanie zasobami ludzkimi*, Wydawnictwo Wyższej Szkoły Bankowej, Poznań 2007.

82 T.S. Oh, S. Park, *A study of the Connected Smart Worker's Techno-stress*, "Procedia Computer Science" 2016, no. 91, p. 725.

shelf, giving institutional brick-and-mortar retailers great power to learn about and influence behaviors and preferences. With the rise of e-commerce, mobile shopping, and most recently smart technologies, new competitors threaten this long-standing supremacy"[83]. This statement shows that new components and features have emerged with the changes in the new industrial revolution that have changed and defined competitors; concepts in the SMART era.

Based on Open Culture in SMART organisations, the technological platform and accompanying Open Resources are developing efficiently. Their essential components are operational efficiency and quality, intensive production methods and scheme development, and efficient and mutual inter-organisational cooperation. Then we should mention the components based on the latest technologies and communication channels, such as advanced and extensive IT infrastructure[84], ICT technologies[85], software integration, and digitisation, causing transformations and virtualisation of production and life of the organisation. Ultimately, it is also worthwhile to raise a significant issue of innovation, which adds components such as research and development and implementing new technologies in the fastest and most efficient way. All these components allow the introduction of a technology platform, the core of which is the SMART Factory[86]. It comprises technology, equipment, workplaces, machines, offices, buildings, organisational structures, space and materials combined with the previous SMART ideology.

In the age of Industry 4.0, organisations have to adapt to new requirements and standards based on the latest communication technologies and frameworks to create SMART Factories. The first element of such a framework is co-creation and SMART product development. Product Life Cycles[87] are becoming shorter and shorter, and the offered products are more and more unique due to growing and continually changing customer preferences. Manufacturers must place great emphasis on innovation and continuously develop the possibilities of the offered products. Currently, most of the products are produced and improved simultaneously. Information is collected and analysed in real-time, eliminating errors and modifying the product several times in one shift.

83 W. Reinartz, N. Wiegand, M. Imschloss, *The impact of digital transformation*…, p. 350.

84 Y.K. Isal, G.P. Pikarti, A.N. Hidayanto, E.Y. Putra, *Analysis of IT Infrastructure Flexibility Impacts on IT-Business Strategic Alignment*, "Journal of Industrial Engineering and Management" 2016, vol. 9(3), pp. 657–683.

85 S. El Kadiri, B. Grabot, K.-D. Thoben, K. Hribernik, C. Emmanouilidis, G. von Cieminski, D. Kiritsis, *Current trends on ICT technologies for enterprise information systems*, "Computers in Industry" 2016, no. 79, pp. 14–33.

86 S. Wang, J. Wan, D. Li, Ch. Zhang, *Implementing Smart Factory of Industrie 4.0: An Outlook*, "International Journal of Distributed Sensor Networks" 2016, no. 4, pp. 1–10.

87 H. Cao, P. Folan, *Product life cycle: The evolution of a paradigm and literature review from 1950–2009*, "Production Planning and Control" 2011, vol. 23(8), pp. 1–22.

Mass Customisation[88] and Mass Personalization[89] are significant here. The customer becomes part of the team planning the product development stages. Another element is the digital factory cooperating with the Internet of Things, enabling a digital connection between all devices and machines. The continuously collected data is analysed in real-time, allowing the machine to make autonomous decisions based on complex algorithms optimising production and management processes. Another element is factory flexibility based on cyber-physical systems[90], which creates a future factory cooperating with self-learning robots. It allows the machine to pass on some of the employees' duties related to ordering the necessary materials, working in challenging conditions that are sometimes impossible for a human being, and the repeatability of production based on continuous correction of minor production errors. The operational excellence and variation reduction are worth noting, enabling different products on the same production line. Constant data analysis and Six Sigma increase the process capability and predictable maintenance by reducing the variation. This approach has a dramatic impact on minimising defects and faults in production processes[91]. Next, the overall organisation's agility and competent workforce enable us to raise the organisation's standards in the future by gaining the ability to adapt to ever-changing requirements. In the age of Industry 4.0, the organisation must be agile in terms of innovative technologies and, above all, develop the ability to adapt employees to new challenges and objectives, both business and engineering. Employees should continuously develop by implementing more and more advanced projects. Creativity, design, programming and process control are highly valued. We should remember eco production, which allows for estimating the environmental impact of production. At the initial stage of production planning, there is always an analysis of the number of harmful substances produced and the number of elements that can be recycled. It is also beneficial to use 3D printing[92], which introduces new raw materials as more eco-friendly substitutes for standard materials.

A perfect example of SMART Factory implementation is the textile industry, which uses a system based on the digital control centre, which allows for a complete analysis of stock levels, current orders, production machines' conditions, and real-time

88 P. Zawadzki, K. Żywicki, *Smart product design…*

89 I.A.R. Torn, T.H.J. Vaneker, *Mass Personalization with Industry 4.0 by SMEs: a concept for collaborative networks*, "Procedia Manufacturing" 2019, no. 28, pp. 135–141.

90 L. Monostori, *Cyber-physical Production Systems: Roots, Expectations and R&D Challenges*, "Procedia CIRP" 2014, no. 17, pp. 9–13.

91 M. Jimenez, M. del Mar Espinosa, M. Dominguez, M. Romero, T. Awad, *Adaptation of the Lean 6S Methodology in an Industrial Environment under Sustainability and Industry 4.0 Criteria*, "Sustainability" 2021, vol. 13(22), 12449.

92 M. Cotteleer, J. Holdowsky, M. Mahto, *The 3D opportunity primer: the basics of additive manufacturing*, Deloitte University Press, Westlake 2013.

production process monitoring. The ERP system is responsible for production management, which transfers the necessary materials to the relevant departments using sensors, lines, and elevators. The next stage is cutting out appropriate blanks from implemented templates. Special machines are responsible for this, which use a laser to mark the outline and cut out the designed shapes at a very high speed. The elements are transported automatically to the next section, the sewing machines. This part is the first section in which machines and people cooperate. The whole process and machine parameters are controlled continuously in real-time. The finished product is transported to the warehouse, packed and prepared for dispatch. Each product has its unique code, thanks to which it is scanned, which minimises the risk of a mismatch.

The last area of the SMART organisation but no less critical is Open Knowledge, defined by Molloy as "the freedom to use, reuse, and redistribute without restrictions beyond a requirement for attribution and share-alike"[93]. It consists of many components, such as effective knowledge management, development, and competence enhancement, by improving employees' skills and knowledge exchange by creating inter-organisational partnerships. Another component is also the sharing of knowledge. In Industry 4.0, sharing knowledge in the technological, business and economic fields is widespread. Then it is worth mentioning effective process management and building competitive strategies. One of the essential components of Open Knowledge concerning the current and previous industrial revolutions is the competitive advantage defined by Rokita as a critical problem in strategic management. It is a condition that allows the organisation to obtain various benefits. When an organisation has a competitive advantage, it has something that others do not have, does something better than others, or does something others cannot do[94]. It also needs to focus on the organisation's direct growth and development by introducing new solutions acquired from others and developed based on knowledge and skills. The approach based on design management and design thinking is also becoming increasingly popular. It is also worth quoting co-creation values presented by Adamik and Nowicki[95]. Co-creation's main benefits are increasing the quality of offered products and services, stimulating employee motivation, reducing and limiting costs and risks, and gaining support and loyalty from business partners and customers[96].

All these components of Open Knowledge allow the creation of knowledge platforms, of which SMART processes are a pillar (see Table 1.7). In SMART terms, direct development is strongly influenced by cooperation and partnership, supply chains,

93 J. Molloy, *The open knowledge foundation: Open data means better science*, "PLoS Biology" 2011, vol. 9(12), para. 2.

94 J. Rokita, *Zarządzanie strategiczne*, Polskie Wydawnictwo Ekonomiczne, Warszawa 2005.

95 A. Adamik, M. Nowicki, *Co-creating value*…

96 A. Adamik, M. Nowicki, K. Szymańska, *Openness to co-creation*…

production, logistics, customer care, systems, grids, and manufacturing. It starts with cooperation, which is very important in exchanging and complementing knowledge among the cooperators, striving to harmonise cooperation in technological and developmental aspects. Then we should mention production, which in the age of Industry 4.0 is moving diametrically towards automation and digitalisation of its necessary parts. An essential link from the process point of view is SMART customers care, which has just been treated as a priority now. The direct cooperation and care of customer satisfaction through scrupulous tracking of purchased products allow for obtaining the appropriate knowledge about the products, services, and users. According to SMART manufacturing, Bogle proposed the following comment "It is mostly framed in terms of better use of big data – that is, measurements and market data – and intra-machine connectivity, particularly using the Internet of things"[97]. In the case of SMART systems, Ho and O'Sullivan proposed the following description of the SMART system as "systems that, by incorporating a wide varieties of networked digital computing and communication technologies, are able to detect, analyse, and respond to the environment in performing smart actions"[98]. SMART logistics is based not only on an intelligent system of delivering products or components but moreover inside the factory using autonomous robots. It enables more efficient transport of elements along designated paths to maintain the appropriate order and hierarchy of distribution of components while monitoring all stages of the process live. Autonomous vehicles also transport components with above-average dimensions or weights exceeding those of ordinary workers or machines used for this purpose. It also minimises the risk of health damage to workers during the delivered components' loading, transport, and unloading. Last but not least, SMART grids are essential. According to Bulkeley, McGuirk, and Dowling, "SMART grids encompass a host of interventions aimed at managing the increasing complexity of (particularly) electricity networks concerning the development of distributed sources of power generation and changing patterns of daily demand, from new algorithms, battery storage, microgeneration technologies, electric vehicles, and forms of demand-side intervention"[99]. According to the definition mentioned above, SMART grids are a crucial element that introduces new forms of communication adapted to the latest communication media used in the age of Industry 4.0. In the data context, we can talk about being constantly online, using abundant data to support ourselves with big data and introducing two-way interchange. In business

97 I.D.L. Bogle, *A Perspective on Smart Process Manufacturing Research Challenges for Process Systems Engineers*, "Engineering" 2017, vol. 3(2), p. 161.

98 J.Y. Ho, E. O'Sullivan, *Strategic standardisation of smart systems: A roadmapping process in support of innovation*, "Technological Forecasting and Social Change" 2017, no. 115, p. 301.

99 H. Bulkeley, P.M. McGuirk, R. Dowling, *Making a smart city for the smart grid? The urban material politics of actualising smart electricity networks*, "Environment and Planning A" 2016, vol. 48(9), p. 1711.

models, we can speak of initiating dynamic business models. The SMART grid enables broad access to information in the technological and production context, implementation of communication between technologies, data on interactions between the various stages of processes, and new possibilities in decision-making features[100]. SMART grids are currently used as sensor networks in manufacturing and wireless networks in telecommunications[101].

Based on the efficient use and development of Open Culture, Open Resources and Open Knowledge, SMART organisations can efficiently generate SMART Products, SMART Services and even SMART Connected Products characteristic of the SMART world. SMART Products are defined by Lin et al. as "A smart product is commonly outfitted with a wide range of sensors (e.g. smart phone with camera, GPS, gyroscope Etc.) to provide various functions, some of which are even running in the background without direct operation of the user (e.g. motion tracking, cloud backup Etc.)"[102]. According to Bucovetchi, Simioana, and Stanciu, "A smart product is characterized by an intelligent sensing technology that is increasingly being integrated with Internet technologies, thereby allowing the product to react to and communicate with the changing environment around it. This leads to optimal operations and improvement in terms of efficiency"[103]. However, according to Brenner and Hummel, "Smart products have in the future solutions incorporated internet based services – designed and manufactured – at the costs of mass products"[104]. SMART Products' concept is complicated because the definition will differ for each industry or organisation type. As far as SMART Services is concerned, they are directly connected to SMART Products. It is worth quoting Lee, Kao, and Yang, "As more software and embedded intelligence are integrated in industrial products and systems, predictive technologies can further intertwine intelligent algorithms with electronics and tether-free intelligence. These technologies will then be used to predict product performance degradation,

100 J. Rodríguez-Molina, M. Martinez-Nunez, J.F. Martinez, W. Perez-Aguiar, *Business models in the smart grid: Challenges, opportunities and proposals for prosumer profitability*, "Energies" 2014, vol. 7(9), pp. 6142–6171.

101 Y. Yan, Y. Qian, H. Shariff, D. Tipper, *A Survey on Smart Grid Communication Infrastructures: Motivations, Requirements and Challenges*, "IEEE Communications Surveys & Tutorials" 2012, vol. 15(1), pp. 5–20.

102 Y. Lin, S. Yu, P. Zheng, L. Qiu, Y. Wang, X. Xu, *VR-based Product Personalization Process for Smart Products*, "Procedia Manufacturing" 2017, no. 11, p. 1569.

103 O. Bucovetchi, A.E. Simioana, R. Stanciu, *A new approach in Supply Chain Processes – Smart Logistics*, "MATEC Web of Conferences" 2017, vol. 121, 07004, para. 3.

104 B. Brenner, V. Hummel, *A Seamless Convergence of the Digital and Physical Factory Aiming in Personalized Product Emergence Process (PPEP) for Smart Products within ESB Logistics Learning Factory at Reutlingen University*, "Procedia CIRP" 2016, no. 54, p. 227.

and autonomously manage and optimise product service needs"[105], which tells the direction in which the development of services based on more technologically advanced products is heading.

1.3. SMART organisations management in the age of Industry 4.0

With the ever-increasing, higher and more diverse demands of the age of industry 4.0 on today's increasingly SMART organisations, their management processes are constantly evolving. More and more strategic and, at the same time, faster changes are required in an increasing number of areas, functions and processes. Hence, the management of organisations is increasingly becoming dynamic management. According to Platonoff, dynamic management is an integrated process based on synthetic knowledge about the organisation and its environment. Together with continuously updating and improving them, decision-makers can direct the organisation constantly to meet stakeholders' expectations[106]. According to Fletcher and Harris, it is a process that will identify and analyse the changes taking place and continually adapt how the organisation operates to them[107]. The speed of changes occurring in the business environment and their qualitative character and unpredictability cause management's basic principles based on people's specialisation and organisational units, and more than top-down or manual management is needed[108]. Indeed, according to Kwiecień, contemporary management is faced with the problem: what to do to meet the individualisation of customers' needs better than the competition – faster and cheaper – in changing and, essentially, unpredictable conditions? In the mainstream of searching for the correct answer, solutions use all the organisation's dynamism, knowledge and human potential. The reason and, at the same time, the manifestation of such activities is the disintegration of the traditional organisation, in place of which large organisations or smaller, dynamic ones are created, consisting of, e.g. associations of independent employees or entities. Such units are characterised by high decision-making autonomy,

105 J. Lee, H.A. Kao, S. Yang, *Service innovation and smart analytics for Industry 4.0 and big data environment*, "Procedia CIRP" 2014, no. 16, p. 3.

106 A.L. Platonoff, *Zarządzanie dynamiczne. Nowe podejście do zarządzania przedsiębiorstwem*, Difin, Warszawa 2009, p. 40.

107 M. Fletcher, S. Harris, *Seven Aspects of Strategy Formation*, "International Small Business Journal" 2002, vol. 20(3), pp. 297–314.

108 P. Płoszajski, *Wstęp: 10 lat w wieku nieciągłości*, [in:] *idem* (ed.), *Przerażony kameleon. Eseje o przyszłości zarządzania*, Fundacja Rozwoju Edukacji Menedżerskiej SGH, Warszawa 2005, p. 10.

speed and independence, higher product quality and more effective management[109]. The specifics of the changes taking place today were aptly put by Drucker, who defined it as flexible, dynamic, multi-tasking, learning-oriented, serving customers, and, most importantly, being open and able to change[110]. In such conditions, an essential Industry 4.0 tool supporting dynamic management is collaborative technology selection management platforms, such as SelectHub[111], which enable more effective and faster decisions based on the latest technological innovations.

The managerial functions identified by H. Fayol have become the basis for the SMART understanding of the process of managerial activities[112]. He developed the principles of managing organisations and defined management as a complex of closely related functions: planning, organising, ordering, coordinating and controlling[113]. In the SMART view, management's essential functions, considered on a functionalist level, are SMART planning and decision-making, SMART organising, SMART motivating and leading, and SMART controlling.

Planning and decision-making are setting goals for the organisation, deciding on the best way to achieve them, and developing a compact hierarchy of plans to integrate and coordinate individual activities[114]. According to Griffin, planning means setting goals for the organisation and determining how best to achieve them[115]. On the other hand, according to Barrow, planning refers to the conscious determination of courses of action and decision-making based on goals, facts and well-considered assessments[116]. Similarly, Krzakiewicz believes that planning is the proper orientation of activities, i.e., success for the organisation in the future[117].

109 A. Kwiecień, *Zarządzanie dynamiczne procesami biznesowymi – wyzwanie dla przedsiębiorstw XXI wieku*, „Studia Ekonomiczne. Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach" 2017, no. 322, pp. 63–73.

110 P.F. Drucker, *Zarządzanie w czasach burzliwych*, Wydawnictwo Akademii Ekonomicznej w Krakowie, Kraków 1995, p. 1.

111 SelectHub, n.d., https://www.selecthub.com/ (accessed: 10.02.2021).

112 S. Lachiewicz, M. Matejun, *Ewolucja nauk o zarządzaniu*, [in:] A. Zakrzewska-Bielawska (ed.), *Podstawy zarządzania*, Oficyna a Wolters Kluwer business, Warszawa 2012, p. 98.

113 A. Czermiński, M. Grzybowski, K. Ficoń, *Podstawy organizacji i zarządzania*, Wyższa Szkoła Administracji i Biznesu w Gdyni, Gdynia 1999, p. 14; K. Fatechi, J. Choi, *International Business Management. Succeeding in a Culturally Diverse World*, Springer, Cham 2019; M.A. Carpenter, T. Bauer, B. Erdogan, *Principles of Management*, Flat World Knowledge, Irvington 2009.

114 A. Zakrzewska-Bielawska, *Istota procesu zarządzania*, [in:] *eadem* (ed.), *Podstawy zarządzania*, Oficyna a Wolters Kluwer business, Warszawa 2012, p. 34.

115 R.W. Griffin, *Podstawy zarządzania organizacjami*, Wydawnictwo Naukowe PWN, Warszawa 2010, p. 9.

116 B. Barrow, *Business plan*, Businessman, Warszawa 1992, p. 12.

117 K. Krzakiewicz, *Teoretyczne podstawy organizacji i zarządzania*, Wydawnictwo Akademii Ekonomicznej w Poznaniu, Poznań 2008, p. 31.

In Industry 4.0, planning plays a vital role. The main assumptions of SMART planning are implemented unprecedentedly considering the latest trends and tools, facilitating the increase of planning effectiveness. Planning without change generally refers to formulating the organisation's primary and specific goals for the specified time using available resources. The goal must always translate into action. Integrating it into the SMART organisation's management to formulate strategy, formal management systems and organisational structures are necessary. The goal must also permeate the informal opinions, views and values that build the organisation's culture[118]. The primary purpose of planning in a SMART organisation is to choose the right strategy and determine the most effective programme of activities to implement decisions. It is also essential to analyse the environment, which in Industry 4.0 changes dynamically and defines its mission, goals, objectives, values, and action directions. It is worth noting that in the age of Industry 4.0, the environment is changeable; therefore, the action plan must be more complex, making it more difficult to define. Thus, the SMART planning process in the age of Industry 4.0 should consider the multivariate nature, an indispensable element of SMART organisations. It includes the shortening of technology and product life cycles, the constant increase in the environment's volatility, high identification and recognition of competitive activities and the continually growing scale of SMART organisation's operations. SMART planning allows managers to make well-considered decisions that virtually affect the achievement of objectives by a SMART organisation.

Planning also forces the organisation's development by creating innovative ideas, helps predict the near future and significantly increases the probability of achieving planned goals. In the age of Industry 4.0, with the introduction of new business models based, for example, on agile management, we can distinguish two levels of planning. On one level, we plan goals and long-term assumptions, e.g. connected with project execution. On the other plane, we have to deal with the division into more miniature stages, each of which has its individual goals and assumptions leading to the implementation of the main tasks, i.e. long-term ones. Another essential element is the available tools based on the infrastructure public in the age of Industry 4.0, which estimates the probability of achieving the planned goals with the highest possible efficiency and the general realisation of a SMART organisation's mission such as monday.com, Celoxis, ClickUp, Kintone, Height, Zoho Projects, Wrike, Kantata, RAIDLOG.com and Forecast[119]. Finally, the planning phase is critical, and the level of its quality or even its absence

118 R.R. Ellsworth, *Cel przedsięwzięcia*, [in:] C.L. Pearce, J.A. Maciariello, H. Yamawaki (eds.), *Dziedzictwo Druckera*, Oficyna a Wolters Kluwer business, Warszawa 2011, p. 76.

119 B. Aston, *20 Best Project Planning Tools To Streamline Delivery in 2024*, 2024, https://thedigitalprojectmanager.com/tools/project-planning-tools/ (accessed: 22.04.2023).

may lead to wrong decisions, significantly affecting the efficiency and effectiveness of the organisation's management[120]. It especially applies to SMART organisations.

The process of organising includes, among other things, the division of tasks, the allocation of resources, the delegation of authority and responsibility, and the organisation of work, so it involves defining tasks and determining who is to perform them. Feedback from employees points out that some people or organisational units feel a significant imbalance in allocating tasks to be carried out, highlighting the excessive burden on other administrative units[121]. Organising is creating an arrangement of people and other resources to enable cooperation to achieve a common goal. This process determines who should do what, who supervises whom, and the relationship between different people and parts of the organisation[122]. The organisational function related to coordinating administrative activities on workstations in organisational units and units becomes even more critical the more significant the organisation is. The more complex the object of its action is, the more numerous and varied its connections with the environment, the more complex the conditions of activity are, and the more varied in geographical space the individual and organisational units are[123].

In the age of Industry 4.0, SMART organising is critical, and that's why it had to stay and be modified about classical approaches. Nowadays, the crucial aspect is the cooperation between the organisation's departments based on direct cooperation between people and machines. Collaboration is carried out fundamentally and through advanced communication media by accepted guidelines. SMART employees must also be open to cooperation with specialists in other fields inside and outside the organisation. Flexibility in organising the SMART process is also essential to adapt to the dynamically changing requirements of the SMART industry and customers. As a result of SMART organising, the organisational structure is created that, apart from people, technology and goals are one of every organisation's most essential elements[124]. In the age of Industry 4.0, a SMART organisation should create suitable organisational structures to efficiently and effectively achieve the objectives and support them in dynamically

120 K. Szymańska, *Planowanie w organizacji*, [in:] A. Zakrzewska-Bielawska (ed.), *Podstawy zarządzania*, Oficyna a Wolters Kluwer business, Warszawa 2012, pp. 167–173.

121 L. Staś, *Elementy etyki w nauczaniu zarządzania na poziomie akademickim w kontekście kształtowania menedżerów w społeczeństwie opartym na wiedzy*, [in:] M. Grzybowski, J. Tomaszewski (eds.), *Bezpieczeństwo w administracji i biznesie*, Wyższa Szkoła Administracji i Biznesu w Gdyni, Gdynia 2007, p. 92.

122 J.R. Schermerhorn, *Zarządzanie*, Polskie Wydawnictwo Ekonomiczne, Warszawa 2008, p. 176.

123 M.J. Stankiewicz, *Zarządzanie przedsiębiorstwem – istota i funkcja*, [in:] B. Godziszewski, M. Haffer, M.J. Stankiewicz, S. Sudoł (eds.), *Przedsiębiorstwo. Teoria i praktyka zarządzania*, Polskie Wydawnictwo Ekonomiczne, Warszawa 2011, p. 251.

124 A. Zakrzewska-Bielawska, *Organizowanie działalności przedsiębiorstwa*, [in:] *eadem* (ed.), *Podstawy zarządzania*, Oficyna a Wolters Kluwer business, Warszawa 2012, p. 253.

changing contexts. Also of great support in this process are up-to-date tools such as Microsoft OneNote, Trello, Google Docs, Canva, Evernote, Airtable, Asana, Penzu, Nimble, Momentum, Habitty and Jira[125].

Motivating and leading are processes related to influencing people, which would arouse their involvement in activities to achieve the organisation's objectives and cooperate with others for its sound[126]. Therefore, the actions taken are intended to provide the SMART organisation with obedient employees and achieve its objectives. These actions are also implemented to satisfy employees' needs, meet their expectations, and increase job satisfaction[127]. According to Griffin, motivation is a set of forces that make people behave in a certain way[128]. According to Armstrong, motivating is about influencing others to move in the desired direction[129]. However, Bieniok et al. write that motivating is about influencing people's fundamentals and behaviour through specific stimuli transformed into motives for action that trigger their activity[130].

In the age of Industry 4.0, SMART motivation[131] plays a critical role in employees' higher education and the emphasis on self-improvement, enabling improved personal and team competencies. Also significant is the effectiveness of the employee built on knowledge and awareness of the work performed. According to such motivation parameters as direction, effort, perseverance, and the employee's emotional state, it is possible to visualise commitments, predisposition, and incentives to stimulate his motivation. However, since time immemorial, including the age of Industry 4.0, money has been considered the most excellent motivator. Nowadays, SMART organisations use an elaborate system that combines an employee's achievements with the possibility of a pay rise. By preparing an annual development plan in various professional and social areas, the employee receives gratification levels that depend on the commitment

125 *11 Powerful Organizational Tools to Help You Work Smarter, Better, Faster*, 2019, https://www.nimble.com/blog/top-ten-organizational-tools/ (accessed: 22.04.2023).

126 A. Zakrzewska-Bielawska, *Istota procesu…*, p. 34.

127 K. Półtoraczyk, *Motywowanie pracowników w klasycznych koncepcjach zarządzania a funkcjonowanie współczesnych organizacji*, "Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu" 2013, no. 277, p. 219.

128 R.W. Griffin, *Podstawy zarządzania…*, p. 518.

129 M. Armstrong, *Zarządzanie zasobami ludzkimi*, Dom Wydawczy ABC, Warszawa 2000, p. 107.

130 H. Bieniok (ed.), *Metody sprawnego zarządzania*, Placet, Warszawa 1997, p. 247.

131 E.-J. Ko, A.-H. Kim, S.-S. Kim, *Toward the understanding of the appropriation of ICT-based Smart-work and its impact on performance in organizations*, "Technological Forecasting and Social Change" 2021, no. 171, 120994; K. Nair, W.F. James, S. Shilbayeh, *An Analysis of the Role of Motivation in Leadership Styles Utilized by Today's Leaders in the "SMART" Organizations in the United Arab Emirates*, "American Journal of Business and Management" 2019, vol. 8(1), pp. 11–17; W.S. Jansen, Ch. Kroger, J. Van der Toorn, N. Ellemers, *The right thing to do or the smart thing to do? How communicating moral or business motives for diversity affects the employment image of Dutch public and private sector organizations*, "Journal of Applied Social Psychology" 2021, vol. 51(7), pp. 746–759.

to the objectives. If the goals are met, the employee gets a salary-proportional increase, which gives them a positive incentive to continue working. On the other hand, if the employee fails to meet their targets, they are directed by their supervisor to follow up training to reach the required level. In the age of Industry 4.0, an employee's education level is higher than just a few years ago due to the handling and cooperation with technologically advanced equipment. Methods of motivation have not changed significantly but have been adapted to the new requirements of continually improving technologies[132]. Also of great support in this process are up-to-date tools such as Gamify by CardioLog, Spinify, Hoopla, TINYPulse and Bottom Line[133].

Controlling, i.e. monitoring the course of the assigned tasks' performance and its results, comparing them with the objectives, and correcting significant deviations so the actual activities are consistent with the planned ones[134]. On the other hand, control aims to detect any irregularities and variations in the prepared plans. According to Koźminski and Piotrowski, control compares the information with what happens during plan implementation, with estimates, budgets, programmes, and patterns developed during planning[135]. According to Robbins and DeCenzo, control is monitoring activities to ensure they are carried out according to the plan and correct any significant deviations[136]. However, Strużycki wrote that control is a systematic activity to set performance standards to pursue goals, design informational feedback, and compare actual performance with the set standards. Moreover, planning sets the organisation's objectives and allocates resources by identifying deviations, measuring their significance, and taking the necessary steps to ensure that all organisation resources are used most effectively and efficiently to achieve the goals[137]. Organising brings together people and other resources defined as structures to accomplish these goals. By motivating and leading, we encourage people to reach them. Controlling, on the other hand, will happen in the right way and at the right time so that the achievement of the objectives can be monitored and evaluated. Control makes it possible to compare what has been planned with what has been done. Such a reference allows the planning function to be

132 A. Walecka, *Podstawy motywowania pracowników*, [in:] A. Zakrzewska-Bielawska (ed.), *Podstawy zarządzania*, Oficyna a Wolters Kluwer business, Warszawa 2012, pp. 324–327.

133 *Motivation Tools for Employees: Gamification and Engagement Ideas*, 2022, https://www.intlock.com/blog/motivation-tools-employees-gamification-engagement-ideas/ (accessed: 22.04.2023).

134 A. Zakrzewska-Bielawska, *Istota procesu*…, p. 34.

135 A.K. Koźmiński, W. Piotrowski, *Zarządzanie. Teoria i praktyka*, Wydawnictwo Naukowe PWN, Warszawa 2010, p. 199.

136 S.P. Robbins, D.A. DeCenzo, *Podstawy zarządzania*, Polskie Wydawnictwo Ekonomiczne, Warszawa 2002, p. 559.

137 M. Strużycki, *Podstawy zarządzania*, Oficyna Wydawnicza SGH w Warszawie, Warszawa 2008, p. 310.

closely linked with the control function[138]. Also of great support in this process are up-to-date tools such as Flowchart, Check Sheet, Cause and Effect (fish bone) Diagram, Pareto Chart, Control Charts, Histograms and Scatter Diagrams[139].

In the age of Industry 4.0, control and planning are greatly influenced by the volatility of the SMART organisation environment. It is also worth adding the influence of factors such as the organisation's complexity, employee error, and managers' need to delegate authority. SMART control[140] is significant in Industry 4.0 because of its information about its development, effectiveness, difficulties, and whether it uses market opportunities appropriately. In the age of automation, the frequency of control is very high due to the greatest possible precision of the activities performed. SMART systems operate based on pre-programmed procedures, which must be carried out by the assumed plan and meet the relevant standards. SMART controls help eliminate uncertainties in the functioning of individual areas of the organisation and increase the likelihood of achieving the goals[141].

In the described management process, the main actors are the managers who should have the competencies to manage in the conditions of the age of Industry 4.0. According to Sheti and Pereira, such competencies include entrepreneurial leadership, agility, business acumen, design thinking, collaborative mindset, problem-solving and decision-making, disruptive leadership, and research orientation. Collaborating in real and virtual teams and communicating effectively are crucial competencies[142]. Integrating the necessary competencies with technological requirements and new assumptions about managers in Industry 4.0 is also essential[143]. It is because managers work in a demanding environment made up of many automated processes run and operated by various devices and software, which requires a division of leadership skills between humans and machines, i.e. they will have an interpersonal relationship with one and a bond with the other developed through sustainable optimisation and modernisation. In this context, it is essential to shorten the distance between the manager and the technology

138 S. Flaszewska, K. Szymańska, *Kontrola w organizacji*, [in:] A. Zakrzewska-Bielawska (ed.), *Podstawy zarządzania*, Oficyna a Wolters Kluwer business, Warszawa 2012, p. 436.

139 P. Lotich, *7 Management Tools for Quality Control*, 2024, https://thethrivingsmallbusiness.com/seven-management-tools-for-quality-control/ (accessed: 22.04.2023).

140 J. Lopez, C. Alcaraz, R. Roman, *Smart control of operational threats in control substations*, "Computers & Security" 2013, no. 38, pp. 14–27; C. Tankard, *The security issues of the Internet of Things*, "Computer Fraud & Security" 2015, no. 9, pp. 11–14.

141 S. Flaszewska, K. Szymańska, *Kontrola*…, p. 422.

142 S.V. Sheti, V. Pereira, *Proposed managerial competencies for Industry 4.0 – Implications for social sustainability*, "Technological Forecasting and Social Change" 2021, vol. 173(4), 121080.

143 A.D. Nowakowski, *Smart factory jako czynnik przewagi konkurencyjnej przedsiębiorstw w kontekście zrównoważonego rozwoju*, [in:] J.W. Pietrewicz (ed.), *Konkurencyjność przedsiębiorstw wobec wymogów zrównoważonego rozwoju*, SGH, Warszawa 2021, p. 134.

(the manager in people-machine communication), the manager and the operating methodology (e.g. the agile manager) and the manager and the organisation (the entrepreneurially oriented manager)[144].

Management under Industry 4.0 conditions also requires a network orientation allowing for the integration of process activities in the information and decision-making sphere and the dynamic interaction of value-oriented entities under conditions of distributed decision-making processes. A significant role is also played by the acquisition and accumulation of available information resources and their processing into helpful knowledge, the use of which may contribute to the shortening of process realisation time, the integration of individual areas of the organisation's operation and the adaptation of the organisation's offer to the needs of the market, taking into account its predispositions and possibilities[145]. A key role is played by implementing advanced IT and technological solutions and introducing management changes, which will allow for the optimal use of intellectual resources and the implementation of operational activities. The use of integrated production planning systems and resource management systems, e.g. Manufacturing Execution System (MES), allows for the performance of actions increasing the efficiency of processes as a result of, among other things, production management, efficiency management, document flow management, resource allocation management, human resources management, data collection and processing, production scheduling[146]. The ability to optimise production processes is key to maintaining high productivity and efficiency, and advanced analytics allows managers to make decisions on planning strategies and production programmes.

All of the indicated solutions resulting from the requirements of Industry 4.0, the pillars of computerisation, artificial intelligence, IoT, Big Data and SMART communication technologies significantly impact an organisation's competitive position. SMART organisations can exploit several competitive advantages, including speed and scope of processing information resources, communication (the ability of systems to collaborate), optimising production processes and flexibility[147]. With new data collection and analysis capabilities, SMART manufacturers can adapt product features based on identified customer needs and market these improvements to gain a competitive advantage. When analysing performance data, the SMART organisation and manufacturers can obtain information that can be used in planning to increase productivity and reduce operating costs[148].

144 K. Prokopowicz, *Kompetencje menedżerskie w rozwoju organizacji SMART*, "Organizacja i Kierowanie" 2022, vol. 192(2), pp. 104–106.

145 L. Kiełtyka, K. Charciarek, *Model zarządzania procesowego z wykorzystaniem nowoczesnych narzędzie przemysłu 4.0*, "Przegląd Organizacji" 2019, vol. 8(955), pp. 5–6.

146 *Ibidem*, pp. 9–10.

147 A.D. Nowakowski, *Smart factory…*, p. 134.

148 *Ibidem*, pp. 126–127.

In turn, implementing a management process in line with Industry 4.0 requirements is linked to the need to adapt to new market challenges and provide customers with products and services while guaranteeing the quality of the customer service process. It is, therefore, necessary to make changes aimed at seeking new value in terms of shaping the principles of cooperation and collaboration with suppliers and customers, searching for new markets, effectively managing the product life cycle, using existing resources and creating new value processing information and generating knowledge. This cooperation is based on digitisation, through which information flows in the value network[149]. In the wake of these changes, a transformation of business models towards a fully networked use of digitisation is also necessary[150]. A business model is a business process architecture, which includes a description of its conceptualisation, the designation of the individual and essential operational steps and the modelling of these processes. It is also an operating philosophy regarded as necessary for developing a future or existing organisation[151]. A business model is considered a strategic planning tool applied at each stage of the organisation's activities and serves better to understand the mechanics of value creation and capture[152].

Traditional business models have often been defined from the perspective of a resource approach, referring to crucial resources, activities and partners viewed through the lens of customer value creation. One example of this approach is Osterwalder and Pigneur's business model describing the rationale behind how an organisation creates value and delivers and profits from this created value. The model consists of nine key elements relating to the four main pillars of the customer, offer, infrastructure and financial credibility[153]. A different approach highlighting the realm of value creation and innovation was presented by Chesbrough and Rosenbloom, pointing to the functions performed by the business model: (i) defines the value proposition – description of target customers, research into their needs, (ii) determines market segments – selection of the target group, research into the needs of individual market segments, (iii) defines the structure of the value chain – this is where management decisions are made that will answer the questions: through what activities should value be delivered to the customer? and how will the organisation capture some of this value?, (iv) specifies

149 B. Gajdzik, S. Grabowska, *Modele biznesowe w przedsiębiorstwach 4.0 – próba identyfikacji założeń użytych do wyznaczenia nowych modeli biznesu*, "Zarządzanie Przedsiębiorstwem" 2018, vol. 21(3), p. 6.

150 J. Niemczyk, R. Trzaska, *Klasyfikacja modeli biznesowych…*, p. 271.

151 K. Firlej, *Model biznesu w zarządzaniu przedsiębiorstwem spożywczym*, "Przedsiębiorczość i Zarządzanie" 2013, vol. 14(13), p. 28.

152 J. Falencikowski, *Strategia a model biznesowy*, [in:] A. Kaleta, K. Moszkowicz (eds.), *Zarządzanie w praktyce i teorii*, „Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu", Wrocław 2012, pp. 81–82.

153 A. Osterwalder, Y. Pigneur, *Tworzenie modeli biznesowych. Podręcznik wizjonera*, Wydawnictwo Helion, Gliwice 2014, p. 5.

the revenue generation mechanism, (v) defines competitive strategies, and (vi) determines growth strategies – identifying directions and areas of growth[154].

The new framework for business models in the age of Industry 4.0 is shaped by changes in the organisational structures of SMART organisations, triggered by the dynamic development of digital technologies that allow businesses to collaborate remotely and communicate efficiently. It also creates opportunities for centralising certain functions, such as accounting or R&D or the creation of virtual global teams. New production capabilities, detailed customer and co-operator databases, digital platforms and data centres, and online customer relationship building stimulate the need to reconfigure existing resources to create new products and services. The dynamic development of information systems has resulted in a new type of risk related to cyber attacks, and its mitigation through adequate security of supply chain operations and data translates into a level of customer trust[155]. These changes have contributed to new business models focused on improving the classic value chain by automating processes and increasing operational efficiency[156] or using a selected type of 4.0 technology in value creation[157].

According to Niemczyk and Trzaska, a business model in the age of Industry 4.0 should meet the following conditions:

- it must combine existing ways of generating value on a serviced basis,
- it must combine in such a way as to ensure the possibility of generating different streams of value,
- it must combine different ways of generating value based on a uniform communication protocol,
- it must combine value streams (pooling transactions) by eliminating all transaction cost carriers,
- it must generate value across the ecosystem,
- all these linking processes must take place using Industry 4.0 technologies[158].

In such a model, the role of business processes is exposed. Three essential elements are considered components of such a SMART model: (i) social-"soft" architecture (knowledge resources, management systems, unique managerial and employee competencies

154 H. Chesbrough, R.S. Rosenbloom, *The role of the business model in capturing value from innovation: evidence from Xerox corporation's technology spin-off companies*, "Industrial and Corporate Change" 2002, vol. 11(3), p. 529.

155 M. Frankowska, M. Malinowska, A. Rzeczycki, *Kształtowanie modelu biznesu w erze industry 4.0*, "Przedsiębiorczość i Zarządzanie" 2017, vol. 18(8), p. 105.

156 J. Niemczyk, R. Trzaska, *Klasyfikacja modeli biznesowych…*, p. 273.

157 C. Burmeister, D. Lüttgens, F.T. Piller, *Business Model Innovation for Industrie 4.0: Why the "Industrial Internet" Mandates a New Perspective on Innovation*, "Die Unternehmung" 2016, vol. 72(2), pp. 124–152.

158 J. Niemczyk, R. Trzaska, *Klasyfikacja modeli biznesowych…*, p. 275.

and employee creativity), (ii) technical-"hard" architecture (IT and telecommunications equipment, computer solutions, robots, 3D printers, Etc.), (iii) business processes as a combination of social (soft) and technical (hard) architecture enabling value creation for the individual customer with very unique and unrepeatable expectations[159].

The literature distinguishes between business models responding to the challenges of Industry 4.0 based on data. Three business models have been identified according to a classification built on the pyramid of value and effort required to produce results. The first, Data as a Service (DaaS), focuses on extracting proprietary insights from data and is based on the value proposition of providing large amounts of processed data with the idea that our customers will provide a service to their customers based on this data. The data in this comes from the organisation's customers or external sources (key partners), is aggregated according to the recommendations of the solution providers and is devoid of sensitive customer data. The second business model, Information as a Service (IaaS), provides more information based on analysing the processed data. This model transforms data into information for customers who need something and are willing to pay for more tailored data. The third model, Answers as a Service (AaaS), involves answering specific questions rather than simply selling information that can be used to answer them. Central to this business model is the organisation's ability to create reliable and trusted value in customer answers, which will generate more value and credibility in the goods received[160].

In turn, the technologies associated with SMART products and services shape the SMART business models responsible for:

- value delivery – the essence of this model is that a SMART product collects information from customers, while the value is the ability to predict the behaviour of the product by its user,
- value creation – this business model includes, for example, activities aimed at providing real information about the product, creating an infrastructure connecting the user with key product partners, changes to the delivery system or even user segmentation,
- value capture – in this business model revenues are created through dynamic pricing, pay-per-use or performance-based revenue[161].

Another classification of Industry 4.0 business models is based on M. Porter's classic approach to competition and the value chain, which has been enriched with elements

159 B. Gajdzik, S. Grabowska, *Modele biznesowe*…, p. 5.

160 Business Models Inc., n.d., https://www.businessmodelsinc.com/big-data-business-models/ (accessed: 10.08.2022).

161 D. Ibarra, J. Ganzarain, J.I. Igartua, *Business model innovation through Industry 4.0: A review*, "Procedia Manufacturing" 2018, no. 22, pp. 4–10, as cited in: J. Niemczyk, R. Trzaska., *Klasyfikacja modeli biznesowych*…, p. 273.

characteristic of this industrial revolution, such as increased flexibility, expanded possibilities for the modular configuration of activities, as well as increased scope for personalisation of products and services[162]. The new business model based on M.E. Porter's modification of the value chain (Net of Value Chain) is a revolution of the previous one, in which the product or service moves one-dimensionally to successive organisational units; in the new industrial reality, value networks are constructed, which are multi-dimensional. The functioning of value networks is based on business platforms that enable the exchange of value created by network participants and facilitate interaction from any applications and devices. A modified value chain is formed by entities with fully automated production lines with automated warehouses, whose devices can communicate directly with each other and coordinate individual activities, resulting in consumers receiving products personalised to them[163].

Table 1.8. SMART enterprises definitions

Author	Proposed definition
Vezaet al., 2014	SMART enterprise mainly uses Cyber-Physical Systems to enable the autonomous exchange of information in machinery, storage systems and production equipment. Its main features are smart, personalised products, product and service providers and high levels of collaboration.
Hernes, 2019	The SMART enterprise uses integration and automation to plan, control and monitor technological and environmental processes and applies artificial intelligence and Big Data solutions and technologies to operate as efficiently as possible.
Impevedo and Pirlo, 2020	SMART enterprises depend on advanced technologies, using and implementing solutions such as integrating artificial intelligence, web technologies, intelligent mobile platforms, telecommunications, e-commerce and e-business.
Rachmaniah et al., 2022	SMART enterprise is based on building a knowledge foundation supported by advanced technology, organisational, leadership and management models.
Wang, 2023	SMART enterprise is a new organisational form of management resulting from digital transformation. It is characterised by the deep integration of the most advanced information, industrial and management technologies. One of the main requirements for its existence and operation is the development of communication technologies such as the Internet of Things and Big Data.

Source: own elaboration based on I. Veza, B. Bilic, N. Gjeldum, M. Mladineo, *Model of Innovative Smart Enterprise*, 6th International Conference on Mass Customization and Personalization in Central Europe (MCP-CE 2014), 2014; M. Hernes, *Towards smart enterprises: supporting the business processes using artificial intelligence*, 2019, http://doi.org/10.48812/uew.wir-yw7f-8x68; D. Impedovo, G. Pirlo, *Artificial intelligence applications to smart city and smart enterprise*, "Applied Sciences" 2020, vol. 10(8), 2944; M. Rachmaniah, A.I. Suroso, M. Syukur, I. Hermadi, *Enterprise Architecture for Smart Enterprise System*, "International Journal of Advanced Computer Science and Applications" 2022, vol. 13(4); X. Wang, *Smart Enterprises in the Context of Digital Transformation: Basic Characteristics and Development logic*, "Journal of Physics: Conference Series" 2023, vol. 2425(1), 012058.

162 J. Niemczyk, R. Trzaska, *Klasyfikacja modeli biznesowych…*, p. 285.

163 B. Gajdzik, S. Grabowska, *Modele biznesowe…*, p. 6.

To sum up, in the literature, the age of Industry 4.0 SMART business models based on SMART market competition strategies include:

- Separation of business models – the business model assumes a low-cost division of the model to create well-functioning single units or individual organisations,
- Long tail – the business model involves focusing on attracting a large number of buyers for niche products,
- Multilateral platforms – the business model assumes access to broad customer groups by offering platform-based access,
- Free as a business model – the business model assumes that at least one significant segment of consumers can benefit from a free product or free service for an extended period,
- Open business model – the business model assumes the creation and preservation of customer value resulting from cooperation with external partners[164].

The presented proposals for classifying business models do not exhaust the total catalogue business behaviour characteristic of SMART organisations in the age of Industry 4.0. SMART organisations should build new business models in stages, observing changes in the existing models. An essential value of the presented SMART models is the treatment of their structure based on overriding values, such as innovation and effectiveness, which are achieved through adequately selected and combined model elements in SMART systems. In further consideration, a group of SMART enterprises (see Table 1.8) was chosen as a contemporary essential type of SMART organisation for better focus on issues raised in the scientific monograph.

164 J. Niemczyk, R. Trzaska, *Klasyfikacja modeli biznesowych*…, pp. 285–286.

2. Building the technological advantage of SMART enterprises

2.1. The essence of competitiveness and competitive advantage of SMART enterprises

From the perspective of building a competitive advantage and competitiveness of an enterprise, it is necessary to start by introducing the term competition. It is identified by Stankiewicz as a phenomenon of participants competing against each other to pursue similar goals, meaning that the actions taken by some to achieve specific goals make it difficult, and sometimes even impossible, for others to achieve the same goals[165]. According to Misala, competition is the ability of different entities operating in a given country to achieve the most significant possible benefits from the social division of labour, more generous than those achieved by the partners to increase the amount of income to be shared within their own country and to better and better meet the diverse needs of customers[166]. Competition is also understood as rivalry between individuals, groups, or organisations interested in achieving the same goal and indicating which economic entity is the best and whether its actions are carried out in the market's correct and desired direction[167]. An extension of this concept would be competing, proposed by Rokita, where two or more undertakings pursuing similar goals act to achieve one's achievement at the other's expense. Competition occurs in markets, which are arenas of competition defined as markets in which activities are carried out that give rise to the phenomenon of competition. Entities are producing the same, similar, or substitute products. Through them, they compete for buyers[168].

Competitiveness is the effect of competition and indicates how enterprises compete in the marketplace for customers' favour[169]. According to Adamik, competitiveness can be regarded as a characteristic of an enterprise that determines its ability to compete

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165 M.J. Stankiewicz, *Konkurencyjność przedsiębiorstwa: Budowanie konkurencyjności przedsiębiorstwa w warunkach globalizacji*, Dom Organizatora, Toruń 2005, p. 18.

166 J. Misala, *Międzynarodowa konkurencyjność gospodarki narodowej*, Polskie Wydawnictwo Ekonomiczne, Warszawa 2011.

167 M. Kraszewska, K. Pujer, *Konkurencyjność przedsiębiorstw. Sposoby budowania przewagi konkurencyjnej*, Exante Wydawnictwo Naukowe, Wrocław 2017, p. 9.

168 J. Rokita, *Zarządzanie…*, p. 70.

169 K. Beyer, *Kapitał intelektualny jako podstawa przewagi konkurencyjnej przedsiębiorstw*, "Zeszyty Naukowe Uniwersytetu Szczecińskiego. Studia i Prace Wydziału Nauk Ekonomicznych i Zarządzania" 2012, no. 25, pp. 241–254.

and achieve a postulated competitive position in the market[170]. However, according to Hammel and Prahalad, competitiveness is the ability to build at a cheaper cost and faster than competitors, the primary skill that generates better products[171]. According to Walczak, competitiveness is an enterprise's multidimensional character resulting from its internal characteristics and the ability to adapt to environmental changes[172]. Abbas defines competitiveness as enterprises' ability to innovate and be flexible, which manifests itself in gaining a competitive advantage[173]. Table 2.1 presents various definitions of competitiveness from national and international literature.

Table 2.1. Selected definitions of competitiveness

Author	Definition of competitiveness
S. Flejterski	The ability to design, produce and sell goods whose price, quality and other qualities are more attractive than the corresponding qualities of competitors' goods.
W. Jakóbik	Relative ability to push one's system of goals, objectives or values.
E. Jantoń-Drozdowska	Enterprise ability to increase the efficiency of its internal functioning by strengthening and improving its position in the market.
J.E. Lombana	Being profitable and maintaining a dominant market position.
M. Lubiński	The enterprise's ability to grow sustainably over the long term and to maintain and expand its market share.
J. Maxwell	Generate economic benefits by improving the quality of human capital.
J. Misala	The ability of various actors within a country to derive the most significant possible benefit from social division of labour, more significant than that achieved by their partners, in order to increase the size of the income to be distributed within their own country and to meet the diverse needs of customers increasingly.
German Specialist Council	The ability to produce unique products and technical solutions, generating income growth under full employment conditions, despite growing competition from newly industrialising countries.
D. Orlowski	Ability to sell.
U. Płowiec	The realisation of the enterprise's profitability rate higher than the prevailing interest rate enables long-term development.
T. Przybyciński	Market acceptance of the enterprise's products and selling the products profitably.
F. Sigurdson	Ability to produce products to withstand international competition while maintaining and growing real GDP.

170 A. Adamik, *Partnerstwo strategiczne a konkurencyjność przedsiębiorstw. Perspektywa MSP*, Wydawnictwo Politechniki Łódzkiej, Łódź 2015, p. 24.

171 G. Hamel, C.K. Prahalad, *Przewaga konkurencyjna jutra: strategie przejmowania kontroli nad branżą i tworzenia rynków przyszłości*, Business Press, Warszawa 1999.

172 W. Walczak, *Analiza czynników wpływających na konkurencyjność przedsiębiorstw*, "E-mentor" 2010, vol. 5(37), pp. 5–12.

173 A.J. Abbas, *Rethinking competitiveness*, "Advances in Competitiveness Research" 2000, vol. 8(1), p. 4.

Author	Definition of competitiveness
A. Stabryła	A measure of the aggregate ability to compete with other enterprises to achieve or maintain a particular competitive position concerning market, financial, technical and organisational criteria.
L. Tyson	The ability to produce products that withstand the international competitiveness test while the country's citizens enjoy a sustainably rising standard of living.
P. Uri	Ability to create conditions for higher incomes.
R. Veliytah and S. Zahra	The ability of the enterprise to match industry leaders in product and organisational standards.
T. Wattanapruttipaisan	Greater efficiency in production and delivery of products compared to competitors.
A. Zorska	Competitiveness is the ability to create and exploit a competitive advantage over other domestic and foreign enterprises resulting from operating in a global market treated uniformly.
K. Żukrowska	The ability of economic entities or their products to adapt to changing conditions, allowing them to maintain or improve their position in the market under global conditions.

Source: own elaboration as cited in E. Szymanik, *Konkurencyjność przedsiębiorstwa – główne aspekty*, "Zeszyty Naukowe UEK" 2016, vol. 5(953), pp. 107–124 based on: J. Misala, *Międzynarodowa konkurencyjność…*, pp. 64–68; D. Guzal-Dec, M. Zwolińska-Ligaj, *Konkurencyjność przedsiębiorstwa a otoczenie lokalne*, [in:] M. Juchniewicz (ed.), *Zarządzanie przedsiębiorstwem w warunkach konkurencji. Determinanty konkurencyjności przedsiębiorstw*, Wydawnictwo Uniwersytetu Warmińsko-Mazurskiego w Olsztynie, Olsztyn 2006, p. 55; K. Kolterman, *Innowacje technologiczne w procesie budowania przewagi konkurencyjnej MŚP*, Difin, Warszawa 2013, p. 46; E. Skawińska (ed.), *Konkurencyjność przedsiębiorstw – nowe podejście*, Wydawnictwo Naukowe PWN, Warszawa–Poznań 2002; O. Flak, G. Głód, *Konkurencyjność przedsiębiorstwa. Pojęcia, definicje, modele, cz. 1*, Wydawnictwo Akademii Ekonomicznej w Katowicach, Katowice 2009, pp. 34–38.

Another complex concept that will be defined is an enterprise's competitiveness, which depends on competitiveness and built competitive advantage. According to Stankiewicz, it is possible to define an enterprise's competitiveness as its ability to efficiently achieve its goals in the market arena of competition[174]. According to Kędzierska, an enterprise's competitiveness is its ability to function in a given industry in free-market economy conditions[175]. However, according to Walczak, an enterprise's multidimensional feature results from its internal characteristics and adaptation to environmental changes[176]. It is also worth mentioning the resource approach that identifies the primary sources of the competitiveness of an enterprise. This approach distinguishes time-based competitiveness, the enterprise's capabilities, the primary role of developing and creating key competencies, the leading role of identifying the enterprise's distinctive capabilities and adapting the domain of action to them, and a concept based on the deconstruction of the traditional vertical value chain[177]. One of the best-known classical theories of the competitiveness of enterprises, in which a key role is played by competitive

174 M.J. Stankiewicz, *Konkurencyjność przedsiębiorstwa…*, p. 36.

175 A. Kędzierska, *Wzrost konkurencyjności przedsiębiorstw poprzez fuzje i przejęcia*, [in:] J. Bieliński (ed.), *Konkurencyjność przedsiębiorstw w świetle Strategii Lizbońskiej*, CeDeWu, Warszawa 2005.

176 W. Walczak, *Analiza czynników…*

177 E. Szymanik, *Konkurencyjność przedsiębiorstwa…*

advantage, is the concept of Porter called the concept of the base of competitive advantage. Its fundamental principle is the search for competitive advantage in a specific sector of the studied enterprise's economy. Porter is also the creator of the concept of five competitive forces characterised as the bargaining power of suppliers, the bargaining power of buyers, the threat of the emergence of substitutes, the threat of the emergence of new competitors and rivalry between competitors[178]. Based on his concepts, Porter introduced three strategies for entities to build and consolidate a competitive advantage: differentiated strategy, cost leadership strategy and focus strategy[179]. It is also worth presenting the enterprise competitiveness classification criteria and assigning them various types of competitiveness in Table 2.2.

As far as new concepts of enterprise competitiveness are concerned, they are built based on a constantly changing and very dynamic market situation, making it possible to build an organisation's competitive advantage in current markets. The new concepts are marketing, entrepreneurship, competition theory, strategic management, innovation, and information technology. Enterprise competitiveness can be considered at many levels of the economy and individuals, as shown in Table 2.3. Also significant was the change from local to global competition with the increasing importance of the globalisation process, which had a powerful impact on the approach to cooperation, reduced mutual competition, and created a common market of customers based on the enterprise agreement.

Table 2.2. Classifications of enterprise competitiveness

Division criterion	Type of competitiveness
Assessment range	Operational competitiveness
	Systemic competitiveness
The moment of assessment	Ex-post competitiveness (the current competitive position, is the result of the enterprise's realised competitive strategy against its rivals)
	Ex-ante competitiveness (future competitive position, is determined, among other things, by the relative ability of an enterprise to compete in the future by its competitive potential; it is, therefore, the competitiveness that is realisable)
Area of occurrence	Competitiveness in the market for a particular type of product and/or services
	Competitiveness in the market of a specific type of products and/or services
	Competitiveness in the market for a specific type of resource
	Competitiveness in a specific territory market (e.g. the competitiveness of an enterprise in the internal market and/or in the international market)

178 M.E. Porter, *Strategia konkurencji. Metody analizy sektorów i konkurentów*, Wydawnictwo MT Biznes Sp. z o.o., Warszawa 2006, p. 63.

179 M. Kraszewska, K. Pujer, *Konkurencyjność przedsiębiorstw…*, pp. 12–13.

Division criterion	Type of competitiveness
Level of competitiveness	Normal competitiveness
	Less than normal competitiveness
	More than normal competitiveness
Observation time	Static competitiveness (the state of competitiveness of an entity at a given point in time)
	Dynamic competitiveness (changes in the state of competitiveness of an entity over time; it is the ability to maintain or improve the previous level of competitiveness)
Actions and effects	Factor competitiveness (related to reaction to changes in the environment, rational use of resources, decision-making processes)
	Resultant competitiveness (related to market share, financial performance against competitors)
Market relationship parties	Competitiveness "on inputs" (the ability to meet targets for acquisition of resources)
	Competitiveness "on the outputs" (the ability to achieve the objectives of gaining market acceptance for the products produced)
	Competitiveness "in action"
Enterprise objectives	Competitiveness from a production volume perspective
	Competitiveness from a cost perspective
	Competitiveness from a production quality perspective
Evaluator and the scope of the evaluation	Competitiveness of the enterprise from the point of view of the customer
	Competitiveness of the enterprise as perceived by the management
	Competitiveness of the enterprise from the owners' point of view
	Competitiveness from the point of view of potential investors

Source: own elaboration based on A. Adamik, M. Nowicki, *Budowa konkurencyjności małych i średnich przedsiębiorstw*, [in:] M. Matejun (ed.), *Zarządzanie małą i średnią firmą w teorii i ćwiczeniach*, Difin, Warszawa 2012, pp. 86–87; J. Walas-Trebacz, *Metody i mierniki oceny konkurencyjności przedsiębiorstwa*, "Przegląd Organizacji" 2013, no. 4, p. 36.

Table 2.3. The levels of the economic system, entities competing and their competitiveness determinants

The level of the economic system	Entities competing at a given level	Determinants of competitiveness
Micro level (enterprises)	– Sole enterprises – Enterprises and their associations	– Management competences – Corporate strategies – Innovation management – Integration into technology networks – Technological entrepreneurship – Cooperation with suppliers, producers and customers
Mezo level	– Industries, sectors, branches, etc.	– Infrastructure policy, education policy, industrial policy, environmental policy, regional policy, export policy, import policy
Macro level	– National economies	– Technological progress – Innovation system – Governance system

The level of the economic system	Entities competing at a given level	Determinants of competitiveness
Mega level	– Group of national economies	– Socio-cultural factors – Value systems – Basic structure – Political-economic – Ability to formulate strategies and policy – Innovation
Global level	– The global economy	– Strategic alliances, mergers and acquisitions – Placement of technology abroad in those areas where economies have a special position in the home country – R&D activities – Technological and organisational progress – Taking advantage of lower labour costs – Innovations in the production process, design, marketing and promotion – Having an appropriate sales network

Source: own elaboration as cited in Z. Chyba, *Przedsiębiorczość technologiczna w procesie kreowania przewagi konkurencyjnej przedsiębiorstw wysokich technologii*, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2021, pp. 105–106 based on: M. Krwawicz, *Innowacje jako czynnik konkurencyjności*, [in:] W. Wiszniewski, E. Głodziński, S. Marciniak (eds.), *Innowacje w działalności gospodarczej. Ujęcie mezo i mikro*, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2017, pp. 65–70.

According to the author, the concept of enterprise competitiveness that best fits further considerations is the one proposed by Stankiewicz, presented in Figure 2.1, that an enterprise's competitiveness is influenced by the enterprise's environment, which is understood all those events, objects, situations, phenomena, and entities that affect the enterprise's competitiveness are not its components. We can distinguish between the general environment, a set of forces and factors of macro character and the competitive environment, understood as forces shaping competition in the sector[180]. According to Porter, the forces shaping competition in the sector may include forces of competitors, suppliers, buyers, substitutable products, substitutable services and the possibility of new competitors entering the sector[181].

180 M.J. Stankiewicz, *Konkurencyjność przedsiębiorstwa…*, p. 86.

181 M.E. Porter, *Competitive Strategy. Techniques for Analyzing Industries and Competitors*, Free Press, New York 1980, pp. 4–33.

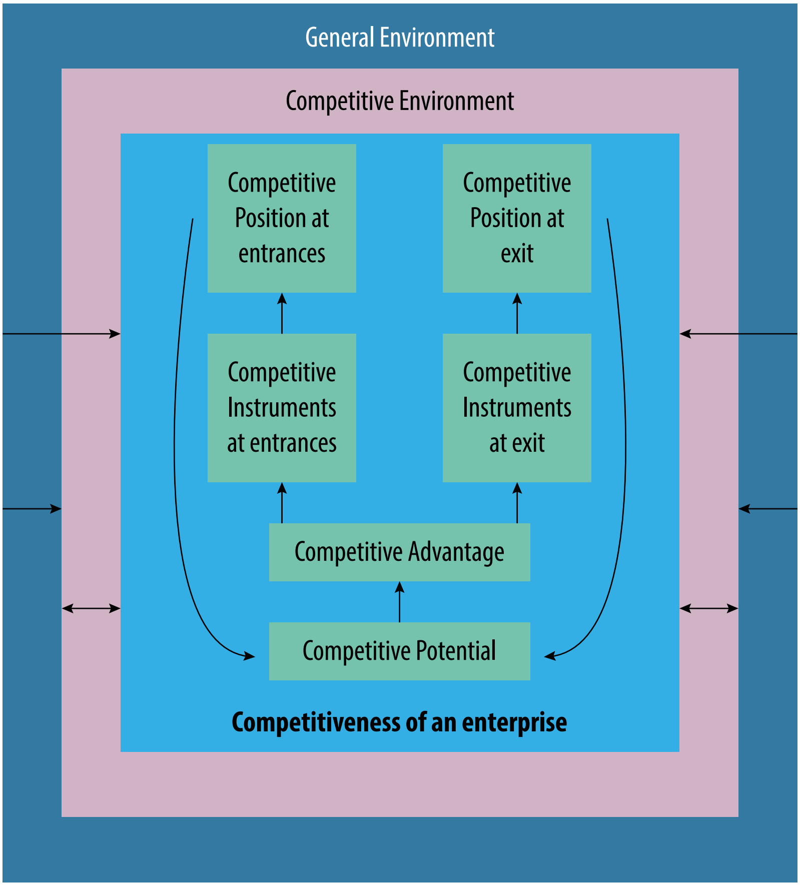

Figure 2.1. A model for the process of building enterprise competitiveness
Source: own elaboration as presented in M.J. Stankiewicz, *Konkurencyjność przedsiębiorstwa…*, p. 87.

Putting the above approaches together, the process of building SMART enterprise competitiveness consists of 4 key stages. In the first stage of building SMART competitiveness, the enterprise consciously and adequately generates its competitive potential according to the requirements of the age of Industry 4.0, which is the starting point for the whole process.

The competitive potential is all an enterprise's tangible and intangible resources necessary to function in the competitive market arena[182]. However, according to Flak and Głód, the competitive potential is a set of structured resources for performing specific functions identical to the value chain theory[183]. According to Gorynia, competitive

182 M.J. Stankiewicz, *Konkurencyjność przedsiębiorstwa…*, p. 89.
183 O. Flak, G. Głód, *Konkurencyjność przedsiębiorstwa…*

potential should be the main element influencing the acquisition and maintenance of competitive advantage[184]. The literature analysis on the subject consists of human resources, physical resources, financial resources, perceptual resources, political resources, organisational resources, intellectual resources, and information resources. The foundation comprises human resources, consisting of personnel, qualifications, training and work performance.

In the second stage of the process of building SMART enterprise competitiveness, the SMART enterprise, from among its competitive potential, aptly selects above-average valuable resources in the age of Industry 4.0 to form the basis of its market differentiation and source of competitive advantage.

The concept of competitive advantage, which is very hard to define. According to Stankiewicz, the competitive advantage of an enterprise can be finally determined as the ability to use the competitive potential in such a way that it is possible to generate an attractive market offer and effective instruments of competition so effectively that it ensures the creation of added value[185]. According to Porter, competitive advantage creates and maintains better results than competitors. There is the soul of an enterprise's performance in competitive markets[186]. According to Adamik, the competitive advantage of an enterprise is its ability to consciously identify, implement, develop, protect and benefit from such unique resources and skills in the scope of all links of the value chain implemented in the organisation, which, being sought and valued on the market, are not available in the same range to other competitors[187]. However, according to Rokita, the competitive advantage of an enterprise is its ability to use resources and conditions of competition on product supply and sale markets in such a way that it enables to generate more added value for the enterprise and its actual and potential customers than the added value generated by its competitors[188]. For Lynch, competitive advantage is achieving more excellent added value than other enterprises operating in the same market[189]. Teece and Pisano claim that an enterprise's dynamic competitive advantage depends not only on its possession of specific vital resources, which are synonymous with certain capabilities, but also on its ability to implement and improve them[190]. Definitions of competitive advantage are very different, which causes

184 M. Gorynia (ed.), *Luka konkurencyjna na poziomie przedsiębiorstwa a przystąpienie Polski do Unii Europejskiej*, Wydawnictwo Akademii Ekonomicznej, Poznań 2002.

185 M.J. Stankiewicz, *Konkurencyjność przedsiębiorstwa…*, p. 172.

186 M.E. Porter, *Competitive Advantage. Creating and sustaining Superior Performance*, Free Press, New York 1985.

187 A. Adamik, *Partnerstwo strategiczne…*, p. 41.

188 J. Rokita, *Zarządzanie…*, p. 61.

189 R. Lynch, *Corporate Strategy*, Pitman, London 1997.

190 D. Teece, G. Pisano, *The dynamic capabilities of firms: An introduction*, "Industrial and Corporate Change" 1994, vol. 3(3), pp. 537–556.

a significant problem in unifying this concept, as can be seen more widely in the following literature concerning strategic management and economics: Azizi et al.[191], Barney[192], Bhaumik, Driffield, and Zhou[193], Burden and Proctor[194], Chen and Zhang[195], Clulow, Gerstman, and Barry[196], Fahy[197], Fahy, Farrelly, and Questeret[198], Filho et al.[199], Kang and Na[200], Liao and Hu[201], Lin[202], Ma[203], Netland and Aspelund[204], Peteraf[205], Por-

191 R. Azizi, M. Maleki, M. Moradi-Moghadam, V. Cruz-Machado, *The impact of knowledge management practiceson supply chain quality management and competitive advantages*, "Management and Production Engineering Review" 2016, vol. 7(1), pp. 4–12.

192 J.B. Barney, *Resource-based theories of competitive advantage: A ten-year retrospective on the resource-based view*, "Journal of Management" 2001, vol. 27(6), pp. 643–650; *idem*, *Gaining and sustaining competitive advantage*, Pearson Hall, New Jersey 2007.

193 S.K. Bhaumik, N. Driffield, Y. Zhou, *Country specific advantage, firm specific advantage and multinationality – sources of competitive advantage in emerging markets: evidence from the electronics industry in China*, "International Business Review" 2015, vol. 25(1A), pp. 165–176.

194 R. Burden, T. Proctor, *Creating a sustainable competitive advantage through training*, "Team Performance Management: An International Journal" 2000, vol. 6(5/6), pp. 90–97.

195 Q. Chen, N. Zhang, *Does E-Commerce Provide a Sustained Competitive Advantage? An Investigation of Survival and Sustainability in Growth-Oriented Enterprises*, "Sustainability" 2015, vol. 7(2), pp. 1411–1428.

196 V. Clulow, J. Gerstman, C. Barry, *The resource-based view and sustainable competitive advantage: The case of a financial services firm*, "Journal of European Industrial Training" 2003, vol. 27(5), pp. 220–232.

197 J. Fahy, *The resource-based view of the firm: Some stumbling-blocks on the road to understanding sustainable competitive advantage*, "Journal of European Industrial Training" 2000, vol. 24(2/3/4), pp. 94–104.

198 J. Fahy, F. Farrelly, P. Quester, *Competitive advantage through sponsorship: A conceptual model and research propositions*, "European Journal of Marketing" 2004, vol. 38(8), pp. 1013–1030.

199 J.M.S. Filho, L.S.O. Wanderley, C.P. Gómez, F. Farache, *Strategic Corporate Social Responsibility Management for Competitive Advantage*, "BAR, Curitiba" 2010, vol. 7(3), pp. 294–309.

200 S. Kang, Y.K. Na, *The Effect of the Relationship Characteristics and Social Capital of the Sharing Economy Business on the Social Network, Relationship Competitive Advantage, and Continuance Commitment*, "Sustainability" 2018, vol. 10(7), 2203.

201 S.-H. Liao, T.-C. Hu, *Knowledge transfer and competitive advantage on environmental uncertainty: An empirical study of the Taiwan semiconductor industry*, "Technovation" 2007, vol. 27(6/7), pp. 402–411.

202 B.-W. Lin, *Technology transfer as technological learning: A source of competitive advantage for firms with limited R&D resources*, "R&D Management" 2003, vol. 33(3), pp. 327–341.

203 H. Ma, *Toward global competitive advantage: Creation, competition, cooperation, and co-option*, "Management Decision" 2004, vol. 42(7), pp. 907–924.

204 T.H. Netland, A. Aspelund, *Company-specific Production Systems and Competitive Advantage: A resource-based view on the Volvo Production System*, "International Journal of Operations & Production Management" 2013, vol. 33(11/12).

205 M.A. Peteraf, *The cornerstones of competitive advantage: A resource-based view*, "Strategic Management Journal" 1993, vol. 14(3), pp. 179–191.

ter[206], Zheng and Chen[207]. Overall competitive advantage comprises partial advantages or disadvantages obtained in specific offers presented in specific market areas. If they occur together, providing added value, the undertaking has an overall competitive advantage, but if it does not, it has no such advantage, considering all the consequences. Partial advantages include technological, resource, relational, information, flexibility, time, manufacturing, offering, and natural advantages, as described in the further subchapter[208].

When measuring competitive advantage from the perspective of an enterprise's managers, four types of competitive advantage can be referred to: internal-oriented advantage, competitor-oriented advantage, customer-oriented advantage and market-led advantage[209]. In each of these four types, we can see a relationship related to the technologies used, which allows us to identify the essence of technological advantage, described in the next section[210]. The meters that will be used to assess the level of an enterprise's competitive advantage from the point of view of the performed considerations will be:

- competence of employees,
- knowledge and technological know-how,
- technological innovations,
- capacity for inter-organisational cooperation,
- customer relations,
- attractive and differentiated offer,
- corporate image,
- financial capabilities,
- price of products/services,
- quality of products/services[211].

These meters were chosen because they indicate the enterprise's future, present and future activities in various areas, such as technologies used, customer loyalty and satisfaction,

206 M.E. Porter, *Competitive advantage of nations*, Free Press, New York 1990; *idem*, *Cluster and the new economics of competition*, "Havard Business Review" 1998, no. 49, pp. 77–90; *idem*, *Competitive advantage: Creating and sustaining superior performance*, Free Press, New York 2008.

207 J. Zheng, S. Chen, *Exploring China's success at the Olympic Games: a competitive advantage approach*, "European Sport Management Quarterly" 2016, vol. 16(2), pp. 148–171.

208 M.J. Stankiewicz, *Konkurencyjność przedsiębiorstwa…*, pp. 178–186.

209 G.S. Day, *Maintaining the Competitive Edge: Creating and Sustaining Advantages in Dynamic Competitive Environments*, [in:] G.S. Day, D.J. Reibstein, R.E. Gunther (eds.), *Wharton on Dynamic Competitive Strategy*, John Wiley & Sons, Inc., New York 1997.

210 Z. Chyba, *Przedsiębiorczość technologiczna…*, pp. 121–124.

211 A. Adamik, *Partnerstwo strategiczne…*

corporate image, short-term and long-term prospects and employee capabilities, which are all together significant for SMART enterprises in the age of Industry 4.0[212].

In the third stage of the process of building competitiveness, SMART enterprises must learn to communicate their competitive advantage to the market properly. Competitive instruments are used for this purpose, and they should be as SMART as possible.

The competitive instruments were described as measures consciously created by the enterprise to acquire contractors for the presented or designed offer[213]. Roszyk-Kowalska defines competitive instruments as tools and ways of developing customers and suppliers on such conditions that enable the enterprise to achieve its goals[214]. Grabska, on the other hand, draws attention to the fact that instruments of competition are significant for the customer differences concerning the enterprise's offer or its behaviour, allowing for gaining customers[215]. Competitive instruments can be divided into three main groups at entry, in operation and exit. Starting with input-entry competition instruments, they mainly concern the size of orders, the repetition of orders, loyalty to the supplier, the form of receipt of goods, a specific form of payment, the determination of the level of the purchase price, the conditions of use of the resource and the destination of the resource purchased. Then we divide the instruments of competition in action into the productivity of specific types of resources, good location concerning sources of supply, sales markets and infrastructure specificity, low manufacturing, labour and logistical costs, high product quality, timeliness, reliability and accuracy of the orders being carried out, the extension of the range of the offer and expansion of brand awareness. Last but not least, we can specify the instruments of competition for enterprises at the exit, consisting of the quality of the offered products, flexibility, availability of new products, availability of service, guarantee conditions, promotions and discounts for regular customers, the brand of the offered product, settlement system, delivery system, pro-environmental features of the offered products, prices of maintenance services, prices of guarantee services, guarantee conditions for post-guarantee repairs and customer loyalty[216].

In the fourth stage of the described process, thanks to aptly selected sources of competitive advantage and the suitable instruments for competing in the SMART market, the enterprise can develop a significant competitive position over time.

212 Z. Chyba, *Przedsiębiorczość technologiczna*…, pp. 121–126.

213 M.J. Stankiewicz, *Konkurencyjność przedsiębiorstwa*…, p. 89.

214 G. Roszyk-Kowalska, *Przewaga konkurencyjna w aspekcie kluczowych kompetencji przedsiębiorstwa*, [in:] P. Płoszajski, G. Bełz (eds.), *Wybory strategiczne firm: nowe instrumenty analizy i wdrażania*, Oficyna Wydawnicza Szkoły Głównej Handlowej, Warszawa 2006.

215 A. Grabska, *Instrumenty konkurowania a trwałość przewagi konkurencyjnej*, [in:] K. Piech, G. Szczodrowski (eds.), *Przemiany i perspektywy polskich przedsiębiorstw w dobie integracji z Unią Europejską*, vol. 2, Instytut Wiedzy, Warszawa 2003.

216 M.J. Stankiewicz, *Konkurencyjność przedsiębiorstwa*…, pp. 241–251.

The competitive position of enterprises is understood as competition in a given sector, considered against competitors' results[217]. According to Flak and Głód, an enterprise's competitive position is defined as its synthetic market and financial results, resulting from the degree of use of its capacity to compete now and in the future[218]. However, according to Porter, an enterprise's competitive position means a constant struggle between competitors; it is dynamic, i.e., changeable over time and can be shaped by the enterprise by choosing a competitive strategy[219]. According to Simmonds, an enterprise's competitive position is a force concerning its direct competitors that determines its future profits or losses[220]. According to Pierścionek, on the other hand, it is the degree to which the enterprise adapts to customer preferences[221]. From the literature analysis, the enterprise's competitive position at the entrance consists mainly of knowledge about suppliers and strictly defined cooperation conditions. The enterprise's competitive position consists of its relative market share, considering its tendency to change, its profit concerning its competitors, and its ability to compete on prices. Then the quality of production, knowledge of the markets, technological capabilities, management of the organisation and its financial situation, and change are also considered. The enterprise's last competitive position at the exit consists of customer knowledge, advertising and marketing activities effectiveness, customer satisfaction, purchasing preferences and consumer tests.

It is essential to measure the level of competitiveness of enterprises well by choosing the right metrics. These meters can be derived from an enterprise's ability to gain a competitive advantage based on selected business skills:

- sales volume,
- profitability of sales,
- sales growth rate,
- break-even point,
- market share,
- market share growth rate,
- share of export sales in total sales revenue, etc.[222]

On the other hand, as shown in Table 2.4, a set of meters for assessing the competitiveness of a SMART enterprise is presented, taking into account the previously

217 *Ibidem*, p. 89.

218 O. Flak, G. Głód, *Konkurencyjność przedsiębiorstwa…*, p. 75.

219 M.E. Porter, *Strategia konkurencji. Metody analizy…*

220 K. Simmonds, *The Accounting Assessment of Competitive Position*, "European Journal of Marketing" 1986, vol. 20(1), pp. 16–31.

221 Z. Pierścionek, *Strategie konkurencji i rozwoju przedsiębiorstw*, Wydawnictwo Naukowe PWN, Warszawa 2003.

222 Z. Chyba, *Przedsiębiorczość technologiczna…*, p. 106.

described elements such as competitive position, competitive potential and the instruments of competition used.

Table 2.4. Meters for assessing a SMART enterprise competitiveness

Meters for assessing competitive position	Meters of competitive potential	Meters of assessment of used instruments of competition
Enterprise share (product) in the market (% sales share, sales dynamics – changes in position)	Funding opportunities: – current operations – development from own funds – development from external funds	Price of product/service
Financial position: profitability, rate of return on investment, added value, etc.	Quality: – executives: finance, marketing, logistics – production, R&D, personnel, export – product/service – motivation system – information system	Quality of product/ service
		Innovation
Number of contracts won to the number of contracts lost (share dynamics of change) – meter of factor competitiveness	Technology: – corporate financial management – production equipment, information technology – the level of innovation – the possibility of acquiring the newest construction and technological solutions	Complexity of offer
		Packaging
	Expenditure on: R&D; marketing activities; employment; logistics	Timeliness of delivery
	Flexibility: – production systems, product range – organisation – pricing policy	Payment and guarantee conditions
	Organisational culture	Advertising and sales production
	The rank given in the enterprise: – quality assurance issues within the enterprise – expansion into foreign markets – marketing activities – R&D	
	Access to: key resources; technology; sourcing; distribution; capital; information, knowledge	Convenience of purchase (availability)

Meters for assessing competitive position	Meters of competitive potential	Meters of assessment of used instruments of competition
	Degree: – development of a clear vision for growth – identification of employees with the enterprise's objectives – knowledge of the enterprise and its products on the markets – knowledge of competitors – knowledge of current and future customer needs – utilisation of production capacity – utilisation of human capital – use of IT infrastructure – perception (reputation, image, renown) of the enterprise	Frequency of introduction of new products Range of after-sales services
	Level: service; competence; knowledge; cost; innovation; availability; management acceptance by staff	Product brand
	Willingness: – of the enterprise (employees) to cooperate – to change	

Source: own elaboration as cited in J. Walas-Trebacz, *Metody i mierniki…*, pp. 40–41 based on M. Gorynia, E. Łaźniewska (eds.), *Kompendium wiedzy o konkurencyjności*, Wydawnictwo Naukowe PWN, Warszawa 2009, pp. 91–98; A. Lipowski (ed.), *Zarządzanie konkurencyjnością przedsiębiorstwa. Wybrane aspekty*, WSB w Dąbrowie Górniczej, Dąbrowa Górnicza 2008, pp. 13–17.

In the context of the age of Industry 4.0, the model of the process of building enterprise competitiveness proposed by Stankiewicz shown in Figure 2.1 must be modified as shown in Figure 2.2.

In the context of Industry 4.0, the basis of competitiveness is no longer just the human being but also their responsibility, awareness of their values and qualifications for everyday work activities. Another component is physical resources, including leading factories, equipment, stocks and machine parks. The introduction of Industry 4.0 is critical for factories' full automation by replacing people with qualified and technologically advanced robots. Then mention should be made of financial resources such as available cash, loans and borrowings, bonds and shares. In the context of Industry 4.0, all new technological solutions generate huge costs directly related to the complete change of technological infrastructure. Considering the requirements of Industry 4.0, an essential source of incurring high prices may be conducting research and development activities. Another set of resources concerns perceptual resources made up of customers, suppliers, competitors and partners. In the context of Industry 4.0, customers have become an essential link in the production chain, as they are both consultants, users and quality controllers. Political resources such as the government and its agendas, local authorities, trade unions and legal regulations are also worth mentioning. Organisational resources include culture, system, structure and decision-making processes. In the context of Industry 4.0, it is worth modifying these resources due to both technological and managerial development.

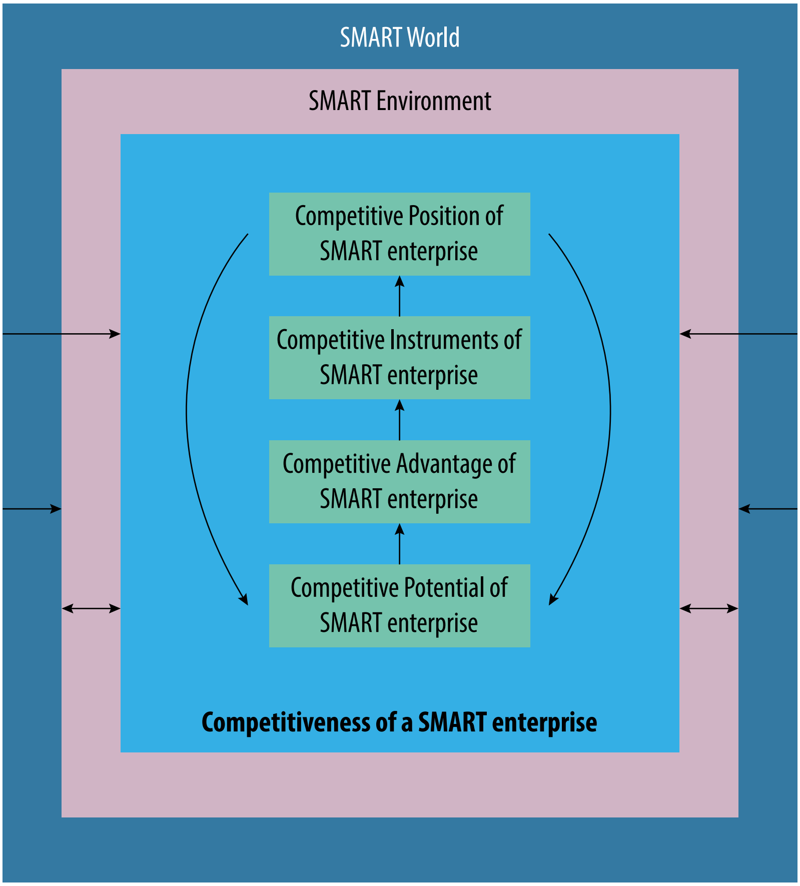

Figure 2.2. A model for the process of building SMART enterprise competitiveness in Industry 4.0
Source: own elaboration based on M.J. Stankiewicz, *Konkurencyjność przedsiębiorstwa…*, p. 87.

From the point of view of Industry 4.0, the most significant impact on the competitive potential of SMART enterprise has intellectual resources, including an analysis of the sector's evolution, macroeconomic changes, technology and innovation. Technologies are increasingly influencing the development and position of an enterprise, and they are the driving force behind innovating innovations and solutions that enable market competition. More critical are information resources consisting mainly of knowledge of recipients' needs, competitors, understanding of the current situation on the market, and knowledge of superiors and staff. In the age of Industry 4.0, information resources can be transferred to a higher level due to the extensive communication networks enabling the acquisition of information in real-time on all necessary topics concerning the services and products offered. Another critical aspect of building the competitiveness of SMART enterprises in the age of Industry 4.0 is the modification of management concerning the classic approach due to the tremendous impact of technology on management and production spheres.

2.2. The essence of building the technological advantage of SMART enterprises

As signalled above, enterprises can build their competitiveness based on diverse sources of competitive advantage. In the age of Industry 4.0, technological advantage is systematically gaining particular importance.

In introducing the essence of building technological advantage, it is necessary to start with a general notion of what technology is? It is a way of transforming a system's resources into the results of this transformation, as products and processes, thanks to the knowledge, equipment, and working methods. The transformation products are tangible goods such as parts of products and intangible goods. A particular type of these goods is information resulting from data processing, which is necessary for decision-making[223].

On the other hand, technology can be considered in five aspects: physical objects and organisation methods; organised inorganic matter[224]; processes, activities, and actions; knowledge, skills and competencies; and learning[225]. Starting from the first aspect, physical objects and methods of organising them, according to Torrkeli and Tuominen, technology is an essential resource that can be used to build a competitive advantage[226]. According to Białoń and Obrębski, technology is a set of material means and methods used in an organisation[227].

According to the next aspect, i.e. considering technology in the context of processes, activities and actions, technology, according to Schlie, is a value chain, a sequence

223 J. Rokita, *Zarządzanie*…, p. 219.

224 K. Halicka, *Prospektywna analiza technologii – metodologia i procedury badawcze*, Oficyna Wydawnicza Politechniki Białostockiej, Białystok 2016, pp. 14–18.

225 B. Stiegler, *Technics and Times. 1. The fault of Epimetheus*, Stanford University Press, Stanford 1998, p. 17.

226 M. Torrkeli, M. Tuominen, *The contribution of technology selection to core competences*, "International Journal of Production Economics" 2002, vol. 77(3), pp. 271–284.

227 L. Białoń, T. Obrębski, *Nauka i technika w rozwoju społeczno-gospodarczym*, Wydawnictwo Naukowe PWN, Warszawa 1989, p. 11.

of interrelated activities performed within final product manufacture[228]. According to Lowe, technology is a structured application of scientific principles and practical knowledge to physical facts and systems[229]. According to Christensen and Raynor, technology is the process that each enterprise uses to transform inputs into higher-value objects[230].

Concerning the aspect of knowledge, skills and competence, according to Steele, technology is necessary to produce goods and services[231]. According to Pacey, technology is an organisation's knowledge, skills, and methods[232]. Trott states that technology is knowledge applied to products and production processes[233]. According to Dosi, technology is a set of practical and theoretical knowledge, skills of its application, methods, procedures, experiments and physical devices that use knowledge[234]. According to Day and Schoemaker, technology is a set of skills in a specific discipline applied to a given product, service, process, or even contributing to creating a new sector[235]. According to Rokita, the basis of technology is knowledge, which is present at three levels depending on its direct relevance to achieving its objectives. These levels are defined as fundamental research, development research and knowledge application. In fundamental research, it is new knowledge. Development research uses existing knowledge. In the case of application, it is disseminating knowledge suitable for relatively rapid and widespread application. Because of the technologies, knowledge in an organisation is supposed to create and increase the value of products for customers, processes, and activities, the value of raw materials, materials, components, and sourcing[236].

Also relevant are the enterprise strategies in technology, a set of investment programmes created to enable the enterprise: research, development and application. The purpose of a strategy is to achieve technical objectives. On the other hand, programmes are collections of projects that serve a specific purpose.

228 T. Schlie, *The contribution of technology to competitive advantage*, [in:] G.H. Gaynor (ed.), *Handbook of Technology Management*, McGraw-Hill, New York 1996.

229 P. Lowe, *Zarządzanie technologią. Możliwości poznawcze i szanse*, Wydawnictwo Śląsk, Katowice 1999, pp. 192–193.

230 C. Christensen, M. Raynor, *The Innovators Solution: Creating and Sustaining Successful Growth*, Harvard Business School Press, Boston 2003, p. 39.

231 L.W. Steele, *Managing Technology – The Strategic View*, McGraw-Hill Book, New York 1989, p. 55.

232 A. Pacey, *The Culture of Technology*, Basil Blackwell Publisher Limited, Oxford 1983, p. 6.

233 P. Trott, *Innovation Management and New Product Development*, Prentice Hall, Harlow 2008, p. 17.

234 G. Dosi, *Technological paradigms and technological trajectories. A suggested interpretation of the determinant and direction of technical change*, "Research Policy" 1982, vol. 11(3), pp. 147–162.

235 G.S. Day, P.J.H. Schoemaker, *A Different Game*, [in:] G.S. Day, P.J.H. Schoemaker, R.E. Gunther (eds.), *Wharton on managing emerging technologies*, John Wiley & Sons, Inc., New York 2000, p. 2.

236 J. Rokita, *Zarządzanie…*, p. 219.

Another essential element for building a technological advantage for SMART enterprises is the technology value chain. It contains basic product and process research, development, and application activities. Each set of homogeneous activities is one step in the chain analysis, and all together form a multi-step chain analysis process of our form and competitor in the technology area. Another element is SMART technological resources, an essential component of any enterprise's technological stock. These resources must be evaluated using various criteria: financial, human, knowledge, physical, perceptual, and organisational. These criteria make it possible to identify the sources of creating the enterprise's resources in technology. Identifying and evaluating these resources is also essential because some organisations often have specialised technology resources, but others are universal and applicable to many units[237].

Another essential aspect is technological capabilities. According to Porter[238] and Burgelman, Christensen, and Wheelweight[239] technological capabilities are essential for competitive advantage of SMART enterprises[240]. However, authors such as Hall believe that the competitive advantage of SMART enterprises exists through technological capabilities and SMART applying and integrating existing technologies[241]. Ritzman and Krajewski argue that technologies and technological capabilities need to be carefully analysed as they can bring advantages (improved product quality and cost reduction) but also disadvantages (investment costs in operations and high volume requirements)[242]. According to Eisend, Evanschitzky, and Calantone, technological capability refers to a SMART enterprise's ability to develop and apply technology to produce new products more efficiently and effectively than competitors. In particular, it relates to a SMART enterprise's ability to use and apply technology in a new product initiative, such as initial technical assessment, prototype development, pilot production and product launch. The stronger a SMART enterprise's technological capability, the more likely it will bring products to market successfully[243].

Having introduced the technology concept, it is worth presenting how it relates to competitive advantage. According to Rokita, technology development to achieve competitive

237 *Ibidem*, pp. 219–220.

238 M.E. Porter, *Competitive Strategy*, Free Press, New York 1980.

239 R. Burgelman, C.M. Christensen, S.C. Wheelweight, *Strategic Management of Technology and Innovation*, McGraw Hill, New York 2004.

240 R.H. Hall, *Organizações: estruturas, Processos e Resultados*, Pearson Prentice Hall, São Paulo 2004.

241 V.A.V. Filho, R.G. Moori, *The role of technological capabilities in the competitive advantage of companies in the Campinas, SP Tech Hub*, "Innovation & Management Review" 2018, vol. 15(3), pp. 247–268.

242 L.P. Ritzman, L.J. Krajewski, *Administração Da Produção e Operações*, Pearson Prentice Hall, São Paulo 2004.

243 M. Eisend, H. Evanschitzky, J. Calantone, *The Relative Advantage of Marketing over Technological Capabilities in Influencing New Product Performance: The Moderating Role of Country Institutions*, "Journal of International Marketing" 2016, vol. 24(1), pp. 41–56.

advantage occurs in two phases. The first consists of strict control of the technologies used so far, and the second phase consists of creating a technology development strategy correlated with the enterprise's overall strategy. The first phase consists of four steps: in-depth supervision and control, area identification, technology identification, and creating a technology and product portfolio. The second phase is based on issues such as technology development and making changes in manufacturing processes[244].

According to Takala et al., technology as know-how is an essential element of resource-based strategy[245] to build sustainable competitive advantage[246]. Therefore, technology has been divided into three main types: basic, core, and spearhead technology, referring to solutions used soon. The importance of the different technology levels in technology-based enterprises substantially impacts implementing strategy through the required knowledge and supports the enterprise's success in the chosen competitive category. According to the study, 40% are basic technologies, 40% are core technologies, and 20% are spearhead technologies. From the view of the technology rankings, the SMART enterprise is competitive and strives to achieve a positive outcome in terms of technology as it seeks to improve the technology in the future[247].

In contrast, according to Hung et al., the main objective of technological competition is to gain a larger market share or increase turnover, which enterprises can achieve through 'catch-up' or 'leapfrogging' strategies[248]. A catch-up strategy is based on the internal development of new technologies when emerging or on imitation and subsequent transfer of mature technologies from multinational enterprises[249]. Intense competition has a powerful impact on the scale of R&D activities by increasing incremental returns to innovation. An accurate catch-up process can only be achieved by acquiring the ability to generate and improve technologies instead of simply using them. Enterprises that grow without sufficient capital and technology use catch-up strategies[250]. It is believed that catching up is not an automatic process but is based on accumulated

244 J. Rokita, *Zarządzanie…*, pp. 216–218.

245 E. Braun, *Technology in Context. Technology Assessment for Managers*, Routledge, London 1998.

246 J.B. Barney, M. Wright, D.J. Ketchen Jr., *The resource-based view of the firm: ten years after 1991*, "Journal of Management" 2001, vol. 27(6), pp. 625–641.

247 J. Takala, M. Muhos, S. Tilabi, M.S. Tas, B. Yan, *Using sustainable competitive advantages to measure technological opportunities*, "Management and Production Engineering Review" 2013, vol. 4(3), pp. 55–64.

248 T.Y. Hung, Y.J. Hsiao, S.W. Wu, *Advantage Management Strategy in Competition via Technological Race Perspective: Empirical Evidence from the Taiwanese Manufacturing Industry*, "The Scientific World Journal" 2014.

249 X. Gao, J. Liu, *Catching up through the development of technology standard: the case of TD-SCDMA in China*, "Telecommunications Policy" 2012, vol. 36(10/11), pp. 817–831.

250 C. Perez, L. Soete, *Catching-up in technology: entry barriers and windows of opportunity*, "Technical Change and Economic Theory" 1988, pp. 458–479.

and assimilated capabilities that require learning. The narrowing of the technological gap by precursors depends mainly on the direction and pace of catch-up[251]. Leapfrogging is another strategy for achieving business success when enterprises face fierce competition. We can divide them into strong or weak depending on the technological gap. Intense leapfrogging is associated with innovation, where it plays a significant role, using which the innovative enterprise must leapfrog the current leader, necessarily making the innovator an outsider[252]. On the other hand, a weak leap occurs when an innovator gains temporary leadership and is challenged by a lagging enterprise in the next race. In the context of a leapfrogging strategy, exploited technological innovation can become a source of long-term productivity and economic growth if dedicated institutions have been established that focus on developing human capital, particularly technical and scientific skills. Technological competition is characterised by SMART enterprises constantly trying to outperform their rivals or avoid being left behind. In innovation competition, enterprises continually increase innovation to increase their competitive power. The primary goal of the technological competition is to gain more market share or increase turnover, which SMART enterprises can achieve through the strategies discussed above. Enterprises willing to invest more in R&D activities will achieve higher R&D turnover; when enterprises invest more in R&D spending, competition becomes intense[253].

According to Feng et al., a SMART enterprise's competitiveness can be divided into four main dimensions. The first assumes that core competitiveness is represented by a SMART enterprise's technological competitiveness, which can help enterprises adapt to changes in the external environment, exploit and capture opportunities, reduce threats from external competitors, and create value for business development. The second assumes that such technological competitiveness is limited to a few existing or potential competitors. The third assumes that scientific and technological competitiveness is complex for other enterprises to imitate. The last assumes that a SMART enterprise's core competitiveness adapts to its growth strategy, so other enterprises cannot imitate it[254]. The core technological capability, the capacity for technological innovation, the productivity of the technology industry and the ability to produce technologically advanced products enable enterprises to maintain a specific sustainable competitive advantage. However, the enterprise's external environment and internal

251 M.Bell, K. Pavitt, *Technological accumulation and industrial growth: contrasts between developed and developing countries*, "Industrial and Corporate Change" 1993, vol. 2(1), p. 157–210.

252 D. Encaoua, D. Ulph, *Catching-up or leapfrogging? the effects of competition on innovation and growth*, "Working Papers from HAL" 2004.

253 T.Y. Hung, Y.J. Hsiao, S.W. Wu, *Advantage Management Strategy…*

254 B. Nguyen, T.C. Melewar, A. Japutra, S.H. Han, C.H.S. Chen, X. Yu, *An investigation of the corporate identity construct in China: Managerial evidence from the high technology industry*, "Journal of Marketing Communications" 2018, vol. 24(8), pp. 779–800.

management decision-making are also crucial. Only when a SMART enterprise continuously adjusts its competitive advantage can it maintain a sustainable competitive advantage and have a sustainable competitive advantage[255].

According to Tilabi et al.[256], technology is one of the main drivers of competition, and it can change the structure of an industry, create new business opportunities or eliminate enterprises. Despite the importance of technology, it is important to stress that technology is only sometimes essential. Technology is vital if it helps enterprises reduce costs, create differentiation and improve the quality of their products. Technology is contained in every value activity, and everything an enterprise does involves some technology[257]. Therefore, technology can have a powerful impact on both cost and differentiation. If a SMART enterprise can discover a better technology to perform a process better than competitors, it can gain a competitive advantage[258].

Since the descriptions above show that technology is essential in building a competitive advantage, it is worth making a hierarchy and systematising the technologies responsible for the technological advantage of SMART enterprises. An attempt at such systematisation is presented in Table 2.5.

Table 2.5. Selected technology topologies as inspirations for classifying technological advantage

Author	Technology type	Description
Consulting company A.D. Little	Basic	All competitors will master technologies long known and widespread in the industry; therefore, their influence on competitive processes is no longer significant.
	Core	Technologies are of decisive importance for the enterprise's competitiveness; their mastery determines its acquisition of the competencies necessary to succeed in the sector.
	Emerging	Technologies under development with limited application in a given period but with significant development potential; maybe critical technologies in the future.

255 B. Feng, K. Sun, M. Chen, T. Gao, *The Impact of Core Technological Capabilities of High-Tech Industry on Sustainable Competitive Advantage*, "Sustainability" 2020, vol. 12(7), 2980.

256 S. Tilabi, R. Tasmin, J. Takala, R. Palaniappan, N.A.A. Hamid, Y. Ngadiman, *Technology development process and managing uncertainties with sustainable competitive advantage approach*, "Acta Logistica – International Scientific Journal about Logistics" 2019, vol. 6(4), pp. 131–140.

257 A. Al Shebli, *A strategic framework for managing transformational change towards sustainability in the Abu Dhabi public sector organization*, PhD Thesis, University of Wolverhampton, Wolverhampton 2016.

258 M.E. Porter, *Technology and competitive advantage*, "Journal of Business Strategy" 1985, vol. 5(3), pp. 60–78.

Author	Technology type	Description
Day and Schoemaker, 2000	Established	In terms of technology, established science basis and applications, evolutionary architecture, standards, functions and benefits. In terms of infrastructure, established value network of suppliers, channels, regulations and standards. In terms of market and customers, well-defined usage patterns and behaviour, and thorough market knowledge. In terms of industry, established structure, well-known rivals and known game rules.
	Emerging	In terms of technology, uncertain science basis and applications, emergent architecture and standards, unknown functions and benefits. In terms of infrastructure, formative value network of suppliers and channels, emergent regulations and standards. In terms of market and customers, formative usage patterns and behaviour, and speculative market knowledge. In terms of industry, embryonic structure, new players as rivals and emergent game rules.
Takala et al., 2013	Basic	Technologies commonly used and that can be purchased or outsourced.
	Core	Enterprise's current competitive technologies.
	Spearhead	Technologies focused on the future.
Chyba, 2021	Basic	The technological foundation of the enterprise, widely available to competitors and its possession, is necessary for functioning on the market, but it does not give the possibility of creating technological and competitive advantages.
	Core	Technologies with the most significant impact on the effect of competitive struggle enable the creation and maintenance of competitive advantage.
	Pace-setting	Technologies at an early stage of development provide have the potential to redefine the basis of competition, can be a disruptive technology development and be a source of technological or competitive advantage.
	Emerging	Technologies that promise to reformulate the basis of competition in the long term require monitoring, and selective support may in the future enable the creation of competitive advantages.

Source: own elaboration based on Z. Chyba, *Przedsiębiorczość technologiczna…*, pp. 45–46; R.A. Goodman, M.W. Lawless, *Technology and Strategy*, Oxford University Press, Oxford 1994; J. Rokita, *Zarządzanie…*, pp. 216–217; Strategor, *Strategie, struktury, decyzje, tożsamość*, Polskie Wydawnictwo Ekonomiczne, Warszawa 2001, p. 148; J. Takala, M. Muhos, S. Tilabi, M.S. Tas, B. Yan, *Using sustainable competitive advantages…*; G.S. Day,P.J.H. Schoemaker, *A Different…*, p. 5.

The above classifications provide exciting support for a fuller understanding and clearer ordering of building an advantage, especially that of technological SMART enterprises.

Generally, competitive advantage consists of partial advantages obtained in specific market areas. Each SMART enterprise creates a bundle of partial advantages adjusted to its capabilities based on which it can build a competitive advantage. Many definitions concerning the representation of partial advantages in the literature are presented in Table 2.6.

Table 2.6. Partial advantages

Partial advantage	Definition
Cost advantage	It consists of having a leading position in the sector in terms of total costs.
Advantage based on standing out	It consists of the ability to produce and present a unique offer.
Advantage based on the concentration	By concentrating, an enterprise can serve its narrow segment more efficiently and effectively than competitors operating on a broader scale. As a result, an enterprise applying concentration either distinguishes itself by better satisfying the needs of its segment, or generates a limited offer at a lower cost, or achieves both.
Information advantage	It is advantageous based on more efficient channels and more relevant information on the line: customer-business-customer.
Time advantage	It reduces the duration of all processes occurring within the framework of creating the concept of an offer, its production, delivery to customers, servicing, etc.
Natural advantage	It is mainly due to a more convenient location concerning resource and sales markets than competitors, the associated better access to these markets, and the patents held.
Price/quality advantage	It consists of minimising the manufacturing costs that need to be incurred to produce a product that can be sold at a given price or in maximising the price of the offer for a given expenditure incurred in its production.
Advantage of a system for handling and offering solutions	It boils down to the enterprise offering a combination of products and services that not only satisfies the customers' essential needs but also facilitates solving their current and future problems, meets their expectations and, in a certain sense, makes them dependent on the enterprise through a whole system of programmes and additional benefits linked to the introductory offer.
Advantage of building barriers to entry	It is about creating a positive feedback loop between the enterprise and its customers.
Production advantage	It can be obtained when an enterprise has better components of its competitive potential than its competitors in functional-resource spheres related to offering creation processes, i.e. R&D, production, quality management and logistics.
Advantage of offering	It is based on having a better relationship between the enterprise and its market counterparties than the equivalent relationship of its competitors.
Management advantage	It consists of managing the enterprise better than its competitors do, which, together with other advantages, makes it possible to create relatively more added value.
Sustainability advantage	It is a relatively stable state of market acceptance of an unchanged offer and unchanged competitive instruments, produced and generated at costs ensuring net profits.
Global advantage	It relies on the enterprise's offer being effectively pursued in markets subject to global competition.
Strategic advantage	It stems from sources inside the enterprise in what is known as the enterprise's underlying strategy, based on the excellence of its competitive potential and the efficiency of its competitive instruments.
Comparative advantage	It can produce an offer at a lower cost than its competitors, which is a function of lower prices for local labour and raw material resources, a relatively favourable political, cultural and technical situation.

Partial advantage	Definition
Local advantage	It boils down to the fact that an enterprise can only compete effectively in certain specific markets. It usually concerns goods for direct consumption, perishable goods or certain types of services.
National advantage	It relates to a country's competitive arena and is driven by specific domestic demand, domestic regulations or country-specific resource prices.
Non-transitory advantage	It is based on the fact that an offer with specific characteristics and certain competitive instruments can bring only a one-off, economically practical market success, the repetition of which, without changing the characteristics of the offer or the competitive instruments, is not possible.
Cultural advantage	It relies on cultural closeness and the ability to communicate effectively, minimising the impact of language barriers and cultural prejudices when working together.
Advantage of vertical integration	It is about reducing opportunistic behaviour on the part of one's partners.
Technological advantage	It refers to the advantage of an enterprise that, through the use of the latest technological solutions, functions more effectively and efficiently than its competitors.

Source: own elaboration based on M.J. Stankiewicz, *Konkurencyjność przedsiębiorstwa*…, pp. 175–187; G.S. Yip, *Strategia globalna. Światowa przewaga konkurencyjna*, Polskie Wydawnictwo Ekonomiczne, Warszawa 1997, pp. 137–141; J. Penc, *Leksykon biznesu*, Wydawnictwo Placet, Warszawa 1997, p. 420; M.E. Porter, *Strategia konkurencji. Metody analizy sektorów i konkurentów*, Polskie Wydawnictwo Ekonomiczne, Warszawa 1992, pp. 51–52; K. Obłój, *Strategia organizacji. W poszukiwaniu trwałej przewagi konkurencyjnej*, Polskie Wydawnictwo Ekonomiczne, Warszawa 1998, p. 73; J.B. Barney, *Gaining and Sustaining Competitive Advantage*, Addison-Wesley Publishing Company, New York 1997, pp. 186–189; Z. Pierścionek, *Strategie rozwoju firmy*, Wydawnictwo Naukowe PWN, Warszawa 1996, pp. 199–201; J. Wind, *Preemptive Strategies*, [in:] G.S. Day, D.J. Reibstein (eds.), *Wharton on Dynamic Competitive Strategy*, John Wiley & Sons, New York–Toronto 2004, pp. 256–276; D.A. Aaker, *Strategic Market Management*, John Wiley & Sons, New York 1992, p. 187; J.R. Williams, *How Sustainable is Your Competitive Advantage?*, "California Management Review" 1992, vol. 34(3), p. 29; S. Carpintero, *The competitive advantages of the Spanish companies in the international toll road industry*, "Journal of Civil Engineering and Management" 2010, vol. 17(4), pp. 483–493; A. Adamik, M. Nowicki, *Budowa konkurencyjności*…; W. Shan, J. Song, *Foreign Direct Investment and the Sourcing of Technological Advantage: Evidence from the Biotechnology Industry*, "Journal of International Business Studies" 1997, no. 28, pp. 267–284; J. Wisła, *Technologiczna przewaga komparatywna krajów europejskich*, [in:] A. Nowosad, R. Wisła (eds.), *Zróżnicowanie rozwoju współczesnej Europy*, Wydawnictwo Uniwersytetu Jagiellońskiego, Kraków 2016, pp. 369–391.

Because of the objectives of this scientific monograph, today's technological advantage is essential. Therefore, in the following section of the study, the author focuses primarily on the technological advantage described in Table 2.7, which was particularly associated with other areas than SMART enterprises. Therefore, the author sees a research gap that allows conducting a complete analysis of the technological advantage of SMART enterprises with a subsequent attempt to define it and its influence on building a SMART enterprise's competitive advantage and competitiveness based on applied technologies.

Table 2.7. Definitions of technological advantage

Author	Definition of technological advantage
Tylecote and Visintin, 2007	Technological advantage can be measured based on the production of new technologies considering the rate of patenting, the overall level of production and the balance of trade in sectors that can be described as technologically demanding.
Mirosław, Żebrowski, and Starczewski, 2013	The economic aspects of achieving and maintaining a technological advantage should cover all stages/phases of product life, considering the program's relay. The cooperation of science, the defence industry and users plays a significant role in this relay.
Zych, 2016	Technological advantage results from a synergy of tangible and intangible aspects that make the possession and use of technical solutions superior to the opponents.
Klich, 2018	The technological advantage is related to the dynamic growth and dependence of the economy on influential factors, such as technology and engineering.
Bahar, Choudhury, and Rapoport, 2020	Gaining technological advantage implies achieving a significant number of patent applications in a specific type of technology that is proportionally larger than the global average.

Source: own elaboration based on J. Zych, *Rola przewagi technologicznej we współczesnych koncepcjach prowadzenia walki zbrojnej – przykład Izraela*, [in:] P. Niwiński, B. Woźniak-Krawczyk, M. Stańczyk-Minkiewicz (eds.), *Specyfika współczesnych konfliktów na świecie*, Uniwersytet Gdański, Gdańsk 2016, pp. 67–69; L. Klich, *Przewaga technologiczna jako element współpracy i rywalizacji państw*, [in:] E. Kancik-Kołtun (ed.), *Wyzwania społeczeństwa informacyjnego. Polskie i ukraińskie doświadczenia*, Wydawnictwo Uniwersytetu Marii Curie-Skłodowskiej, Lublin 2018; T. Mirosław, Z. Żebrowski, Z. Starczewski, *Współpraca nauki i przemysłu w osiąganiu przewagi technologicznej na polu walki – cykl życia systemów uzbrojenia*, "Zeszyty Naukowe WSOWL" 2013, vol. 1(167), p. 118; A. Tylecote, F. Visintin, *Corporate Governance, Finance and the Technological Advantage of Nations*, Routledge, London 2007, pp. 1–5; D. Bahar, P. Choudhury, H. Rapoport, *Migrant inventors and the technological advantage of nations*, "Research Policy" 2020, vol. 49(9), 103947.

In building a technological advantage, the key elements are identifying the types of technologies owned, presented in Table 2.8 based on previous literature examples, and determining the current enterprise's technological potential.

Table 2.8. Selected technology types by author

Technology type	Description
Basic	Technologies available on the market enable the enterprise to function, and they are the basis for other activities toward technology development and implementation. They also refer to freely available technologies that can be purchased.
Core	Technologies that are more individual for a given enterprise as they form the current set of competitive technologies. These technologies can be sold to other enterprises after a certain period of use as a finished product.
Emerging	Pioneering, innovative technologies that are not available on the market are created due to the R&D activity of an given enterprise. Very high costs and uncertainty characterise their regard to use.

Source: own elaboration.

The technological potential can be treated as a component of competitive potential, including the technological level of products, R&D facilities, quality of production, product and technology life cycle phase, and know-how[259]. Wiśniewska treats it as a set of technologies available to individual economic entities. This understanding consists of codified knowledge (projects, formulas, sketches, production instructions), the knowledge possessed by individuals and teams working in the enterprise (some recorded in enterprise procedures and organisation), and machinery and equipment[260]. However, according to Chyba, technological potential can be identified with the notion of the technological portfolio of a given enterprise, which consists of a specific set of technologies it uses. This portfolio can be divided into families of technologies in terms of the scope and nature of their usefulness and their age, degree of advancement, or, finally, their impact on the enterprise's competitiveness. However, one cannot limit oneself to technological spheres in creating competitiveness in an enterprise. However, one should consider other components of technological potential such as conducting R&D activity, the effectiveness of R&D activity, abilities and predispositions of employees to develop and technological changes[261]. Table 2.9 shows the set of determinants of the technological potential of an enterprise.

Table 2.9. Technological potential determinants

Author	Technological potential determinants
Szatkowski, 2016	Technological expertise
	Technological creativity of the enterprise
	Intangible assets, including know-how
	Intellectual potential of the enterprise's employees
	Effectiveness and efficiency of technology transfer
	Comparability of competing technologies
Chyba, 2021	Technology portfolio
	Intangible assets, including know-how
	Effectiveness and efficiency of R&D activities
	Technological entrepreneurship of the enterprise
	Intellectual potential of knowledge employees
	Competitiveness of available technologies

Source: own elaboration based on Z. Chyba, *Przedsiębiorczość technologiczna…*, pp. 52–53; K. Szatkowski, *Zarządzanie innowacjami i transferem technologii*, Wydawnictwo Naukowe PWN, Warszawa 2016, p. 278.

259 Z. Chyba, *Przedsiębiorczość technologiczna…*, p. 52.

260 J. Wiśniewska, *Zarządzanie zasobami technologicznymi przedsiębiorstw*, [in:] J. Wiśniewska, K. Janasz (eds.), *Innowacyjność organizacji w strategii inteligentnego i zrównoważonego rozwoju*, Difin, Warszawa 2012, p. 74.

261 Z. Chyba, *Przedsiębiorczość technologiczna…*, pp. 50–52.

Based on the literature, the following determinants of technological potential were selected by the author because they fully allow assessing the level of development of technological potential, which is necessary to fulfil the considered objectives of the scientific monograph:

- technology portfolio,
- intangible assets, including know-how,
- effectiveness of R&D activity,
- technological entrepreneurship,
- intellectual potential of employees,
- competitiveness of available technologies.

Summarising the information cited so far based on a critical analysis of national and international literature, the author provides his proprietary definition of the technological advantage of the SMART enterprise. According to the author, the technological advantage is one of the partial advantages of building a competitive advantage of SMART enterprise, which depends on the enterprise's technological potential level of development. It refers to the enterprise's advantage by using the latest technologies to strengthen the market position and improve its quality of action. It can be divided into levels, which determine whether the technological advantage is one of the vital partial advantages in the process of building the competitive advantage of SMART enterprise or it is just another component that does not bring anything extraordinary to the overall process of building the enterprise's competitive advantage. Its division can be created using basic technologies, core technologies and emerging technologies by a SMART enterprise in the age of Industry 4.0.

2.3. Review of conditions for building the technological advantage of SMART enterprises

When considering the presence of conditions that build technological advantage, it is worth linking to competitive advantage, of which is a partial advantage. Three dominant forces determining the functioning of SMART enterprises in the market can be distinguished: globalisation, rapid technological progress, and the growing importance of intellectual capital. From the point of view of building technological advantage, rapid technological development is the most significant. The technological advantage is typically associated with SMART enterprises that create and use the latest technologies. The leading role of knowledge, vision management, R&D work, time pressure, core competencies, and critical personnel defines this type of enterprise. It is also characterised by high innovation, global market coverage, and shorter technology life cycles. Key competencies include change and innovation management, intellectual capital management, selection of key personnel, implementation systems, and changes to the market[262]. Therefore, it was decided to select key conditions for building the technological advantage of SMART enterprises, such as technological innovation capability, technology commercialisation capability, technology transfer performance, and technological capacity.

One of the key conditions of building a technological advantage is technological innovation capability, which according to Chuanpeng et al.[263], consists of technological innovation capability for the product (Product IC) or technological innovation capability for the process (Process IC). Product IC refers to SMART enterprises that can meet customer needs by creating, designing and developing new products[264]. Depending on its novelty, we can distinguish two types of product innovation incremental and radical. Incremental innovation refers to new products that have changed slightly regarding technology, function or appearance. On the other hand, radical innovation refers to products that have undergone significant technical changes characterised by innovation[265]. In contrast, Process IC is equated with improving and developing a product and its manufacturing processes through technical advances[266]. Improving the capability for process innovation, primarily through innovation and optimisation of the product development process, allows the SMART enterprise to accelerate product research and development, reduce research and development costs and increase the capacity for product innovation[267]. Technological innovations enable SMART enterprises to meet customer requirements for the products and services they currently offer and significantly impact the satisfaction of new needs of increasingly demanding customers. Moreover, SMART enterprises with a high capacity for technological innovation are more adventurous

262 H. Majkowska-Godlewska, E. Skrzypek, M. Płonka, *Przewaga konkurencyjna w przedsiębiorstwie. Sektor – Wiedza – Przestrzeń*, Texter, Warszawa 2016, pp. 31–33.

263 Y. Chuanpeng, Z. Zhengang, L. Chunpei, J.W. Yenchun, *Knowledge Creation Process and Sustainable Competitive Advantage: The Role of Technological Innovation Capabilities*, "Sustainability" 2017, vol. 9(12), 2280.

264 C. Camisón, A. Villar-López, *Organizational innovation as an enabler of technological innovation capabilitiesand firm performance*, "Journal of Business Research" 2014, vol. 67(1), pp. 2891–2902.

265 A.K. Chatterji, K.R. Fabrizio, *Using users: When does external knowledge enhance corporate product innovation?*, "Strategic Management Journal" 2014, vol. 35(10), pp. 1427–1445.

266 J.L. Hervas-Oliver, F. Sempere-Ripoll, C. Boronat-Moll, *Process innovation strategy in SMEs, organizationalinnovation and performance: A misleading debate?*, "Small Business Economics" 2014, no. 43, pp. 873–886.

267 C. Camisón, A. Villar-López, *Organizational innovation…*

and willing to look for new solutions, markets and customers because they are not afraid to go beyond their limits. This approach directly impacts the enterprise and can offer new products and services[268]. According to Ortega, technological innovation capabilities improve the relationship between quality and cost performance orientation, suggesting that SMART enterprises should combine the theoretical resource-based view and competitive strategy to achieve better results[269]. Technological innovation capabilities are related to product innovation, as they directly affect production and investment capabilities. In conjunction with strategic supply chain management, technological innovation capabilities affect the performance of a SMART enterprise[270] and the unconstrained management of technological change[271]. To summarise, we can distinguish the capability dimensions in Table 2.10, determining technological innovation capabilities.

Table 2.10. Technological innovation capability dimensions

Capability dimensions	Description
Learning capability	The ability of a SMART enterprise to identify and assimilate explicit knowledge in the environment.
R&D capability	The ability of a SMART enterprise to integrate R&D strategy with project execution.
Resource allocation capability	The power of a SMART enterprise to raise sufficient capital, specialists and technologies for the innovation process with an analysis of the stability of resources, skills and abilities.
Manufacturing capability	The power of a SMART enterprise to transform the results of R&D into products that meet the needs of the consumer market.
Marketing capability	The ability of a SMART enterprise to advertise and sell its products.
Organisational capability	The ability of a SMART enterprise to provide organisational mechanisms that are compatible with the corporate culture, and adoption of good management practices.
Strategic planning capability	The ability of a SMART enterprise to identify its strengths, weaknesses, opportunities and threats, and to formulate action plans in line with the enterprise's vision and mission.

268 H. Mao, S. Liu, J. Zhang, Z. Deng, *Information technology resource, knowledge management capability, and competitive advantage: The moderating role of resource commitment*, "International Journal of Information Management" 2017, vol. 36(6A), pp. 1062–1074.

269 M.J.R. Ortega, *Competitive strategies and firm performance: technological capabilities moderating roles*, "Journal of Business Research" 2010, vol. 63(12), pp. 1273–1281.

270 J. Shan, D.R. Jolly, *Technological innovation capabilities, product strategy, and firm performance: the electronics industry in China*, "Canadian Journal of Administrative Sciences/Revue Canadienne Des Sciences De L'administration" 2013, vol. 30(3), pp. 159–172.

271 R.C.M. Yam, W. Lo, E.P.Y. Tang, A.K.W. Lau, *Technological innovation capabilities and firm performance*, "International Scholarly and Scientific Research & Innovation" 2010, vol. 4(6), pp. 1056–1064.

Capability dimensions	Description
Industrial organisation capabilities	The ability of a SMART enterprise to be attractive on the basis of technical aspects of production, thus determining its position in the market.
Market processes capabilities	The ability of a SMART enterprise to stimulating entrepreneurial activity, creating innovation and generating knowledge to strengthen the concept of innovation.
Dynamic capabilities	The ability of a SMART enterprise to have an evolving set of resources, competencies and capabilities that are able to update and regenerate the enterprise's resource base.

Source: own elaboration in V.A.V. Filho, R.G. Moori, *The role of technological capabilities*… based on J. Guan, N. Ma, *Innovative capability and export performance of Chinese firms*, "Technovation" 2003, vol. 23(9), pp. 737–747; C.M. Yam, J.C. Guan, K.F. Pun, P.Y. Tam, *An audit of technological innovation capabilities in Chinese firms: some empirical findings in beijing, China*, "Research Policy" 2004, vol. 33(8), pp. 1123–1250; A.K.W. Lau, R.C.M. Yam, E.P.Y. Tang, *The impact of technological innovation capabilities on innovation performance*, "Journal of Science and Technology Policy in China" 2010, vol. 1(2), pp. 163–186; P. Ghenawat, *Commitment: The Dynamic of Strategy*, Free Press, New York 1991; M.E. Porter, *Competitive Strategy*, Free Press, New York 1980; C. Shapiro, *The theory of business strategy*, "RAND Journal of Economics" 1989, vol. 20(1), pp. 125–137; J.B. Barney, *Firm resources and sustained competitive advantage*, "Journal of Management" 1991, vol. 17(1), pp. 99–120; R.A. D'Aveni, R. Gunther, *Hypercompetition: managing the Dynamics of Strategic Maneuvering*, Free Press, New York 1994; R. Jacobson, *The 'Austrian' school of strategy*, "Academy of Management Review" 1992, vol. 17(4), pp. 782–807; R. Amit, P. Schoemaker, *Strategic assets and organizational rent*, "Strategic Management Journal" 1993, vol. 14(1), pp. 33–46; I. Dierickx, K. Cool, *Asset stock accumulation and suistanability of competitive advantage*, "Management Science" 1989, vol. 35(12), pp. 1504–1511; R. Sanchez, A. Heene, H. Thomas, *Dynamics of Competence-Based Competition: theory and Practice in the New Strategic Management*, Elsevier, Amsterdam 1996, pp. 1–35; D.J. Teece, G. Pisano, A. Shuen, *Dynamic capabilities and strategic management*, "Strategic Management Journal" 1997, vol. 18(7), pp. 509–533; Y.C. Tang, F.M. Liou, *Does firm performance reveal its own causes? The role of bayesian inference*, "Strategic Management Journal" 2010, vol. 31(1), pp. 39–57; R.R. Wiggins, T.W. Ruefli, *Sustained competitive advantage: temporal dynamics and the incidence and persistence of superior economic performance*, "Organization Science" 2002, vol. 13(1), pp. 81–105.

Another key condition of building technological advantage is technology commercialisation capability. It is crucial to start with the definition of technology commercialisation, which is the ability of a SMART enterprise to use and exploit technology in its products[272]. The concept of technology commercialisation can also be presented as a process of acquiring ideas, improving them based on knowledge, in the next stage, developing and manufacturing products for the market and finally selling them[273]. This way of looking at technology commercialisation is crucial for developing and selling products and ensuring a competitive advantage. Technology commercialisation is oriented towards the inward investment of SMART enterprises, which extensively use their resources and capabilities[274]. However, SMART technology-based enterprises, character-

272 T.M. Nevens, G.L. Summe, B. Uttal, *Commercializing Technology: What the Best Companies Do?*, "Planning Review" 1990, vol. 18(6), pp. 20–24.

273 W. Mitchell, K. Singh, *Survival of Businesses Using Collaborative Relationships to Commercialize Complex Goods*, "Strategic Management Journal" 1996, vol. 17(3), pp. 169–195.

274 L. Aarikka-Stenroos, B. Sandberg, *From New-Product Development to Commercialization Through Networks*, "Journal of Buisness Research" 2012, vol. 65(2), pp. 198–206.

ised by high risk and uncertain outcomes, emphasise their technology commercialisation, primarily based on innovation activities[275]. Furthermore, technology commercialisation is seen in managing associated secrets and patents and introducing new products faster than competitors. It enables SMART enterprises to discover new market opportunities and gain a competitive advantage more efficiently than their competitors[276]. That is why SMART enterprises need to commercialise their advanced technologies. Furthermore, the ability to commercialise technology is defined as all activities and processes that create added value through the transfer, exchange, dissemination and application of advanced technology. Its scope includes the speed of commercialisation, the market and the product's technical scope[277].

The positive effect on technology commercialisation capabilities is related to knowledge management, quality management, competitive intelligence activities, sustainable competitive advantage and business performance. The data used for the acquisition, the latest technology, and product manufacturing are the basis of internal knowledge management in SMART enterprises[278].

Extensive and complete data can therefore enhance future commercialisation opportunities. Consequently, the knowledge management base of the SMART enterprise seeks knowledge processes and absorbs this knowledge, improving its ability to create new technical knowledge to solve problems[279]. Moreover, departments responsible for research and development in today's enterprises can rely entirely on knowledge management, which allows them to tailor a course of action that includes uncertain and unknown options[280]. If the technical knowledge of a SMART enterprise expands and reaches higher and higher levels, it enables the management to know and understand in depth the limitations and weaknesses of R&D taking into account internal aspects. It improves the efficiency of the decision-making process, which has a powerful influence on creating innovations through implementing more effective

275 Y. Li, L. Li, Y. Liu, L. Wang, *Linking Management Control System with Product Development and Process Decisions to Cope with Environment Complexity*, "International Journal of Production Research" 2005, vol. 43(12), pp. 2577–2591.

276 X.M. Song, C.A. Di Benedetto, L.Z. Song, *Pioneering Advantage in New Service Development: A Multi-Country Study of Managerial Perceptions*, "Journal of Product Innovation Management" 2000, vol. 17(5), pp. 378–392.

277 J. Kim, B. Seok, H. Choi, S. Jung, J. Yu, *Sustainable Management Activities: A study on the Relations between Technology Commercialization Capabilities, Sustainable Competitive advantage, and Business Performance*, "Sustainability" 2020, vol. 12(19), 7913.

278 *Ibidem*.

279 W. Zheng, B. Yang, G.N. McLean, *Linking Organizational Culture, Structure, Strategy, and Organizational Effectiveness: Mediating Role of Knowledge Management*, "Journal of Business Research" 2010, vol. 63(7), pp. 763–771.

280 S. Moorthy, D.E. Polley, *Technological Knowledge Breadth and Depth: Performance Impacts*, "Journal of Knowledge Management" 2010, no. 14, pp. 359–377.

R&D processes. Effective R&D based on knowledge management ultimately leads to developing new products, improving them and acquiring more creative technologies and integration capabilities[281].

The increased emphasis on quality in SMART enterprises has a powerful impact on introducing and implementing a quality culture[282]. It will enable quality management based on the established culture and work organisation[283]. By increasing quality, a SMART enterprise can offer better and better quality products, significantly increasing the trust of new and more demanding customers[284]. Activities focused on quality significantly impact the continuous improvement of products and technological development. Quality is one of the factors which creates added value in a SMART enterprise through the improvement of process capabilities leading to the intensive development of creative technology[285].

To sum up, the commercialisation of technology improves the development and implementation of new technologies on the market, increasing the competitiveness of a SMART enterprise and its goods and services[286]. Nevertheless, successful technology commercialisation elaborates on business performance and enhances SMART enterprises' advancement and competitiveness[287]. Determinants related to the acquisition and commercialisation of the technologies as a summary are presented in Table 2.11.

281 P.N. SubbaNarasimha, S. Ahmad, S.N. Mallya, *Technological Knowledge and Firm Performance of Pharmaceutical Firms*, "Journal of Intellectual Capital" 2003, vol. 4(1), pp. 20–33.

282 D.I. Prajogo, A.S. Sohal, *The Integration of TQM and Technology/R&D Management in Determining Quality and Innovation Performance*, "Omega" 2006, vol. 34(3), pp. 296–312.

283 K. Baird, K. Jia Hu, R. Reeve, *The Relationships Between Organizational Culture, Total Quality Management Practices and Operational Performance*, "International Journal of Operations & Production Management" 2011, vol. 31(7), pp. 789–814.

284 A. Gupta, J.C. McDaniel, S. Kanthi Herath, *Quality Management in Service Firms: Sustaining Structures of Total Quality Service. Managing Service Quality*, "Journal of Service Theory and Practice" 2005, vol. 15(4), pp. 389–402.

285 V.R. Kannan, K.C. Tan, *Just in Time, Total Quality Management, and Supply Chain Management: Understanding Their Linkages and Impact on Business Performance*, "Omega" 2005, vol. 33(2), pp. 153–162.

286 D.Y. Li, J. Liu, *Dynamic Capabilities, Environmental Dynamism, and Competitive Advantage: Evidence from China*, "Journal of Business Research" 2014, vol. 67(1), pp. 2793–2799.

287 J. Kim, B. Seok, H. Choi, S. Jung, J. Yu, *Sustainable Management Activities…*

Table 2.11. Determinants of the acquisition and commercialisation of new technologies

Determinants		
Technology acquisition	Implementation of technologies	
	Internal	External
– High costs of conducting research work – Access to ideas – Access to the knowledge necessary to create innovations – Scope of protection for inventions innovation – Access to qualified R&D personnel – Experience in carrying out research – Access to infrastructure for scientific research – Access to funding for R&D – Level of profitability of the investment and associated risks – Customer requirements	– Technical capabilities and possession of resources to enable, for example, testing, production – Organisational capacity and having the resources for, e.g. distribution, marketing activities, security in terms of human resources, and others – Access to information and new market knowledge – The success of the existing business model – Previous experience of the enterprise in the implementation of innovation/technology – The reputation of the enterprise – Funding opportunities – Knowledge, skills and competence of the management – The vision of the top management – The need/willingness to create – New customer needs – The convergence of objectives between the enterprise and its partners – Cost-effectiveness – Level of protection of intellectual property – Membership in a cooperation network – The size of the enterprise – The flexibility of the enterprise (ease of responding to change)	– Opportunities arising from external networking opportunities (existing or potential strategic alliances or other forms of cooperation) – Customer requirements – Requirements of suppliers or other business partners – Sector structure and intensity of competition within the sector – Age of the sector and its growth – Profitability of the sector – The pace of change technology (e.g. shorter product life cycles, technologies) – Barriers to entry into the sector – The threat of substitution – Vulnerability to globalisation – Susceptibility to Asian market influences – The pro-innovation policy of countries – Legal regulations – Specifics of the local business environment – Access to external sources of finance

Source: own elaboration in E. Gwarda-Gruszczyńska, *Modele procesu komercjalizacji nowych technologii w przedsiębiorstwach. Uwarunkowania wybory – kluczowe obszary decyzyjne*, Wydawnictwo Uniwersytetu Łódzkiego, Łódź 2013, p. 163.

A different key condition of building technological advantage is technology transfer performance. Technology transfer projects significantly impact economic progress by increasing the competitiveness of SMART local enterprises in the national and international markets and by achieving better results for the enterprises that are recipients of these technologies[288]. On the other hand, technology transfer performance is defined

288 B.-W. Lin, *Technology transfer…*

as implementing technology transfer projects with foreign enterprises by SMART local enterprises[289]. The link between transferred technology, knowledge and competitive advantage is essential[290]. Knowledge-based technology transfer strengthens the potential of SMART enterprises, which can use technology in an increasingly effective way to compete both nationally and internationally[291]. Technology transfer is a complicated and highly complex process that requires the involvement of all participants at every level (e.g. enterprises, universities, government, scientists, R&D specialists, CEOs, and policymakers), given that they have different goals, values and interests. Technology transfer is an essential link to innovative business and economic development. Three main technology transfer models can be distinguished: linear, non-linear parallel-sequential, and non-linear back feed models[292]. Nowadays, as technology development and complexity increase, models are evolving dynamically, taking into account the critical success factor that determines the effectiveness of technology transfer from the moment of discovery by researchers through finding business applications to using the appropriate technology to market it[293].

According to Santikarn, we can distinguish four main concepts measuring technology transfer performance depending on the different stages of technology transfer. The first concern is that when a SMART enterprise thoroughly uses the transferred technology called the recipient, it is considered to be transferred, allowing the technology to be transported. The second concept assumes that technology can be transferred when the local workforce can comprehend it, but the transfer is completed if they can use it with understanding in the most effective way. The third concept is that once the technology has been dispersed among the structures of a SMART enterprise, it is only then transferred. The transferred technology is believed to be delivered to different enterprise sections through advanced and dynamic distribution activities in the SMART enterprise called the recipient. The last concept assumes that technology transfer can only be observed when skilled employees can adopt and implement the transferred technology into their business environment[294].

289 M. Gilbert, M. Cordey-Hayes, *Understanding the process of knowledge transfer to achieve successful technological innovation*, “Technovation” 1996, vol. 16(6), pp. 301–312.

290 M.A. Al-Abed, Z.A. Ahmad, M.A. Adnan, *Technology transfer performance and competitive advantage: Evidence from Yemen*, “Asian Social Science” 2014, vol. 10(3), pp. 195–204.

291 G.S. Lynn, R.B. Skov, K.D. Abel, *Practices that support team learning and their impact on speed to market and new product success*, “The Journal of Product Innovation Management” 1999, vol. 16(5), pp. 439–454.

292 S. Hilkevics, A. Hilkevics, *The comparative analysis of technology transfer models*, “Entrepreneurship and Sustainability Issues” 2017, vol. 4(4), pp. 540–558.

293 R. O’Shea, T.J. Allen, C. O’Gorman, F. Roche, *A Review of Academic Entrepreneurship Literature*, “Irish Journal of Management” 2004, vol. 25(2), pp. 11–29.

294 M. Santikarn, *Technology transfer: A case study*, Singapore University Press, Singapore 1981.

As far as technology transfer is concerned, it depends on the absorption capacity of the technology[295]. If the transferred technology is implemented and used by a SMART enterprise, it will allow working practices to be improved in the short term, allowing standards to be introduced that are used and practised in the longer term. Technology transfer also contributes to the knowledge and ability to adopt increasingly advanced technologies in SMART enterprises[296]. Technology transfer also significantly impacts the competitive advantage of SMART local enterprises in developing countries[297]. The perceived benefits can be seen in the increased efficiency of projects, maximisation of profits, personal and general development, minimisation of production costs with improved product quality, and the ability to learn new things in production and business[298]. Technology transfer is an excellent opportunity for SMART local enterprises to acquire added value in technology beyond their budget or unavailable due to a lack of research and development activities[299]. Technology transfer is one of the primary sources of competitive advantage for a SMART enterprise. It is directly connected with the technological advantage, which can be defined as one of the vital partial advantages in building the competitive advantage of a SMART enterprise taking into account technological aspects.

Another key condition of building a technological advantage is the SMART enterprise's technological capacity. Technological capacity is the ability to perform any significant technical functions or activities within the boundaries of the undertaking, including the ability to produce new products and processes efficiently[300]. It is based on a SMART enterprise's knowledge based on experience and prior learning processes[301]. The basis of technological capacity is the possession of unique technological resources, including owned patents, personnel in contact with the technological sphere and technological knowledge, the strategic value of which is differentiated, and thus

295 L.W. Steele, *Evaluating the technical operation*, "Research Technology Management" 1988, vol. 31(5), pp. 11–18.

296 A.H. Gold, A. Malhotra, A.H. Segars, *Knowledge management: an organizational capabilities perspective*, "Journal of Management Information Systems" 2001, vol. 18(1), pp. 185–214.

297 R. Takim, R. Omar, A.H. Nawawi, *International technology transfer (ITT) projects and development of technological capabilities in Malaysian construction industry: A conceptual framework*, "Asian Social Science" 2008, vol. 4(8), pp. 38–46.

298 E.M. Rogers, *Diffusion of innovations*, Free Press, New York 1995.

299 W.A. Sazali, A. Haslinda, C.R. Raduan, *A holistic model of the inter-firm technology transfer based on integrated perspective of knowledge-based view and organizational learning*, "The Journal of International Social Research" 2009, vol. 2(9), pp. 408–422.

300 M.J.R. Ortega, *Competitive strategies…*

301 K.J. Mayer, J.A. Nickerson, *Antecedents and Performance Implications of Contracting for Knowledge Workers: Evidence from Information Technology services*, "Organization Science" 2005, vol. 16(3), pp. 225–242.

the value of the strategic potential of the SMART enterprise[302]. SMART enterprises with higher technological capacity seek information about the changing environment, constantly using the acquired knowledge to create innovative products and services that meet domestic and foreign markets[303]. Technological capacity has a powerful influence on the use or application of various technological means concerning the ability of a SMART enterprise to use technology. It enables the enterprise to manufacture products and offer increasingly sophisticated services according to specifications and work schedules[304]. Over time, the technological capacity of the SMART enterprise becomes very valuable and unique, resulting in it being embedded in the organisation's routines and allowing it to adapt more quickly and accurately to upcoming changes[305]. Technological capacity is linked to technical knowledge, which enables the current state of knowledge and stock of skills[306]. By acquiring new information and skills, the SMART enterprise becomes more competent in acquiring knowledge from external sources in all the necessary fields that affect technological aspects, enabling it to build up experience and develop the ability to learn[307]. Much effort is put into research and development while acquiring a SMART enterprise's technological capabilities. It enables the enterprise to broaden its horizons by finding new solutions and products, acquiring the necessary knowledge and training relevant personnel[308]. As a result, the SMART enterprise can quickly identify new technology trends, experiment with emerging projects and engage in product innovations outside the enterprise's current technological boundaries[309]. However, it is worth mentioning that enhancing technological capacity is linked to the innovation discovery process. A high technological capacity only sometimes goes hand in hand with a positive impact on discovering innovations. A SMART enterprise may be satisfied with the current technological level in a given field and neglect the search for new solutions and knowledge bases

302 A. Strybała, *Agregatowa zdolność rozwojowa jako miernik wartości potencjału strategicznego przedsiębiorstwa*, "Prace i Materiały Wydziału Zarządzania Uniwersytetu Gdańskiego" 2009, vol. 2/2, pp. 594–604.

303 J. Karpacz, *Zdolność technologiczna i innowacje produktowe: ujęcie teoretyczne i wyniki badań empirycznych*, Wydawnictwo Uniwersytetu Ekonomicznego w Katowicach, Katowice 2014, pp. 55–67.

304 C. Haeussler, H. Patzelt, S.A. Zahra, *Strategic Alliances and Product Development in High Technology New Firms: The Moderating Effect of Technological Capabilities*, "Journal of Business Venturing" 2012, vol. 27(2), pp. 217–233.

305 K.Z. Zhou, F. Wu, *Technological Capability, Strategic Flexibility, and Product Innovation*, "Strategic Management Journal" 2010, vol. 31(5), pp. 547–561.

306 F.E. Garcia-Muina, J.E. Navas-Lopez, *Explaining and Measuring Success in New Business: The Effect of Technological Capabilities on Firm Results*, "Technovation" 2007, vol. 27(1/2), pp. 30–46.

307 J. Karpacz, *Zdolność technologiczna…*

308 A. Afuah, *Mapping Technological Capabilities into Product Markets and Competitive Advantage: The Case of Cholesterol Drugs*, "Strategic Management Journal" 2002, vol. 23(2), pp. 171–179.

309 J. Karpacz, *Zdolność technologiczna…*

related to innovative solutions[310]. In addition, absorbing new knowledge can be difficult in SMART enterprises that have already acquired considerable technological experience. The acquisition of entirely new knowledge from outside the existing field requires a change of mindset and may be related to the need for prior learning to assimilate the new knowledge[311]. Selected knowledge development indicators defining the level of the technological capacity of the SMART enterprise are presented in Table 2.12.

Table 2.12. Selected knowledge development indicators defining the level of technological capacity of the SMART enterprise

Area: Volume and structure of investment in knowledge development
– R&D expenditure concerning total expenditure – R&D expenditure allocated to fundamental research, product or process design and implementation research – R&D expenditure by enterprise in a given industry – the share of R&D expenditure in the value added of the enterprise's sales
Area: Effectiveness of knowledge inputs
– Measures of the stock of R&D capital, e.g. the quality of scientific research units, the number of scientists and engineers involved in R&D activities, the quality of services of specialised research institutions and training institutions – Availability to the industry of the newest technology – Patents and innovations of various kinds developed and implemented – Basis newly created indigenous products and processes (product and process innovations), including capital goods – Modifications of imported substitutes – Indicators of scientific activity of enterprise employees, such as scientific publications, including co-authorship of papers and the scale of cooperation between universities and enterprises in terms of joint innovation activities

Source: own elaboration in M. Majewska, *Ocena zdolności technologicznych kraju*, [in:] C.F. Hales (ed.), *Nierówności społeczne a wzrost gospodarczy*, Wydawnictwo Uniwersytetu Rzeszowskiego, Rzeszów 2013, p. 174.

Summarising the considerations in subchapters 2.2 and 2.3, a visualisation of the process of building a technological advantage of SMART enterprises in the age of Industry 4.0, shown in Figure 2.3, was created.

It seems that the determinants of the process of building a technological advantage of SMART enterprises operating in the age of Industry 4.0, collected above, are precise determinants of the effectiveness of their competitive actions, hence in the following subchapter, they will be used to try to create a tool for assessing the level of technological advantage of SMART enterprises in the age of Industry 4.0.

310 W.M. Cohen, D.A. Levinthal, *Absorptive Capacity: A New Perspective on Learning and Innovation*, "Administrative Science Quarterly" 1990, vol. 35(1), pp. 128–152.

311 J. Karpacz, *Zdolność technologiczna...*

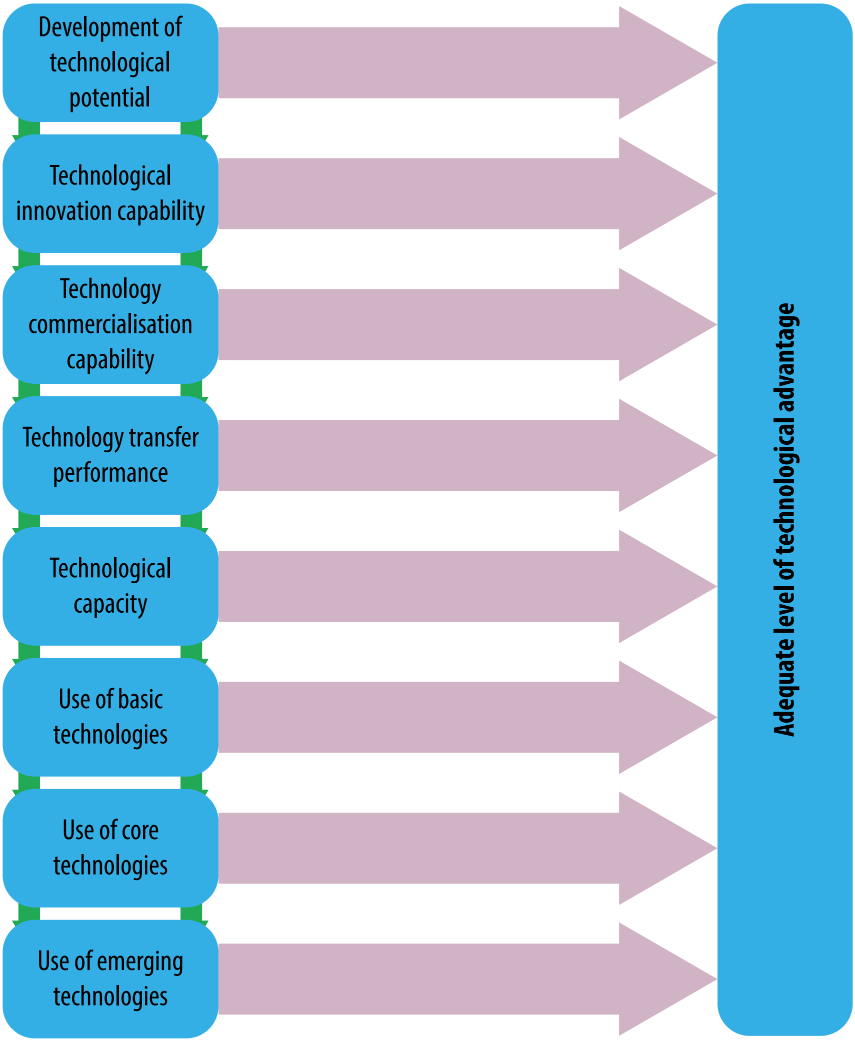

Figure 2.3. Process of building a technological advantage of SMART enterprises in the age of Industry 4.0

Source: own elaboration.

2.4. Assessment of the level of technological advantage of SMART enterprises in the age of Industry 4.0

In this subchapter, summarising the previous considerations, an exploratory model will be presented, which illustrates the location of technological advantage in the overall process of building competitiveness of SMART enterprises in Figure 2.4. and the technology assessment process. Building a technological advantage can also be seen as a process similar to building an enterprise's competitiveness; simultaneously, it is one of its key stages.

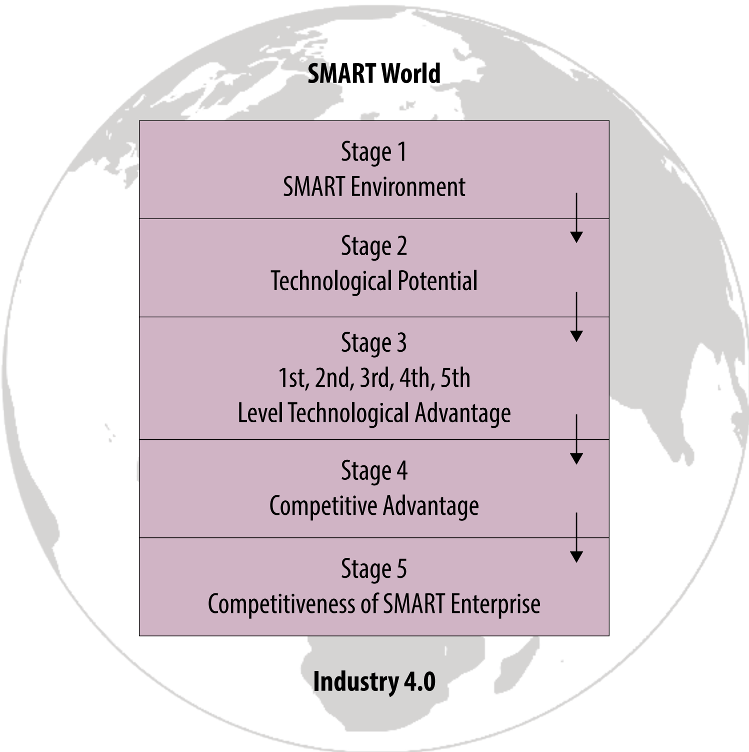

Figure 2.4. Exploratory model

Source: own elaboration.

Figure 2.4 presents a visualisation of the environment of the SMART world based on technologies and other solutions specific to the age of Industry 4.0 inside. We can see increasingly clear elements divided into stages that lead to the achievement of competitiveness by the SMART enterprise, considering the importance of technological advantage. Stage 1 relates to an enterprise's understanding of the SMART environment, i.e. the specifics and requirements of the age of Industry 4.0 and the SMART world environment. Stage 2 relates to the skilful building of the SMART enterprise's technological potential under these conditions. Stage 3 is associated with developing a level of technological advantage adequate to the capabilities and needs of the SMART enterprise. Five levels are possible in this regard. Stage 4 is the culmination of the previous three steps in achieving a specific level of competitive advantage of a given SMART enterprise, thanks to the developed level of technological advantage. Stage 5 is a summary and, simultaneously, the effect of the entire process, which is the competitiveness of SMART enterprises.

The following descriptions of the different levels of technological advantage were introduced for further consideration:

1st level of technological advantage refers to a SMART enterprise that relies on basic technologies and cooperates with suppliers, customers and investors. It analyses the market for new technologies available for the enterprise and future use. The tasks of such a SMART enterprise are to analyse its economic situation constantly and, as far as possible, to explore the potential of its technologies and to compare itself in the context of other SMART enterprises operating on the market and having the same level of technological advantage.

2nd level of technological advantage refers to a SMART enterprise that relies on basic technologies. It knows the technologies currently used by competing enterprises and cooperates with suppliers, customers and investors. Management looks for sources of new technology both inside and outside the enterprise. SMART enterprise analyses the market for new technologies available for the enterprise and future use. SMART enterprise having this level, cooperates with external developers of new technologies and seeks employees to create and implement them. It also monitors the behaviour of competitors in developing and implementing new technologies. SMART enterprise can assess technological potential from the point of view of the market, the relationship to the enterprise's strategy, the necessary investments and the expected return on investment. A SMART enterprise having this level is characterised by the ability to assess the risks of implementing new technologies and evaluate the impact of technologies on product innovations and business processes. SMART enterprises achieving this level of technological advantage are entirely dependent on the achievements of others while saving a large part of the budget that in other enterprises is spent on technology development. On the other hand, SMART enterprises with this level of technological advantage do not need to have a developed machinery park, and they can fully adapt on an ongoing basis to acquire technological solutions from competitors. It is also an appropriate location for new SMART enterprises just trying to start their adventure with advanced technologies or significantly modify technological processes, fully adjusting to the requirements of Industry 4.0.

3rd level of technological advantage refers to a SMART enterprise that relies on basic and core technologies. Investments in R&D activities and cooperation with external R&D centres, e.g. universities, are performed. When creating and developing new technologies, the enterprise relies on the competence and willingness to bear management's risks, technological potential, and financial capacity. It knows the technologies currently used by competing enterprises and cooperates with suppliers, customers and investors. Management looks for sources of new technology both inside and outside the enterprise. SMART enterprise analyses the market for new technologies available for the enterprise and future use. SMART enterprise having this level, cooperates with external developers of new technologies and seeks employees to create and implement them. It also monitors the behaviour of competitors in developing and implementing new technologies. SMART enterprise can assess technological potential from the point of view of the market, the relationship to the enterprise's strategy, the necessary investments, the possibility of commercialising the technology and the expected return on investment. A SMART enterprise having this level is characterised by the ability to assess the risks of implementing new technologies and evaluate the impact of technologies on product innovations and business processes. SMART enterprises with this technological advantage refrain from performing R&D activities on new technologies that fall into the emerging technologies category. SMART enterprises of this level are unwilling to acquire emerging technologies due to a sufficient technological level determined by the advancement of owned basic and core technologies. However, SMART enterprises with this level of technological advantage still have the task of developing core technologies as a competitive attribute. Developed extensions of core technologies may be sold or designed for specific business partners based on required specifications.

4th level of technological advantage refers to a SMART enterprise that relies on basic and core technologies. R&D activities are carried out, which entail investment and development of infrastructure, development of staff, cooperation with external research centres, e.g. universities, and systematic verification of the competence of staff in the context of developing new technologies. Unfortunately, the intensity of R&D activities does not allow the creation of emerging technologies to a great extent. SMART enterprises at this level are trying to create emerging technologies, but they need to be more advanced to achieve an advantage or derive the highest possible added value from them. However, advanced extensions of core technologies may be sold or developed for specific business partners based on required specifications. When creating and developing new technologies, the enterprise relies on the competence and willingness to bear management's risks, technological potential, and financial capacity. It knows the technologies currently used by competing enterprises and cooperates with suppliers, customers and investors.

Management looks for sources of new technology both inside and outside the enterprise. SMART enterprise analyses the market for new technologies available for the enterprise and future use. SMART enterprise having this level, cooperates with external developers of new technologies and seeks employees to create and implement them. It also monitors the behaviour of competitors in developing and implementing new technologies. SMART enterprise can assess technological potential from the point of view of the market, the relationship to the enterprise's strategy, the necessary investments, the possibility of commercialising the technology and the expected return on investment. A SMART enterprise having this level is characterised by the ability to assess the risks of implementing new technologies and evaluate the impact of technologies on product innovations and business processes. The enterprise adopts approaches to implementing new technologies such as watch and wait, position and learn, sense and follow, believe and lead.

5th level of technological advantage relates to the same scope as the 4th level, differing in that it is based on basic, core and emerging technologies that result from ongoing R&D activities. The high intensity of R&D activities makes it possible to create emerging technologies to a large extent. SMART enterprises at this level create emerging technologies to gain an advantage and derive the most value from them. However, advanced extensions of emerging technologies can be sold or developed for specific business partners based on required specifications. Thanks to the creation and implementation of emerging technologies, SMART enterprises belonging to this level set trends and new technological development directions, enabling them to be pioneers in this field and achieve a competitive advantage.

Based on the introduced division, it is possible to determine whether the technological advantage of a given SMART enterprise is one of the significant partial advantages in building a competitive advantage. It is known that SMART enterprises achieving a 5th level of technological advantage have a higher probability that the applied technological solutions and the enterprise's policy impact building a competitive advantage. However, according to the division, SMART enterprises that achieve the technological advantage of the other lower levels also have a chance to consider technological advantage as one of the more critical partial advantages in building competitive advantage. For investigating the technological advantage of a SMART enterprise according to the proposed division into levels of technological advantage, it is necessary to perform a technology assessment process.

Many different models have been described in the technology assessment and selection literature. These models include many areas of evaluation such as technical, business, intellectual and industrial property protection, ethical and environmental aspects, usually referring to single criteria that can be used to rank technologies. In line with the undertaken theme of this scientific monograph, technology assessment models focused on business aspects containing the following assessment areas were reviewed and presented in Table 2.13.

Table 2.13. Technology assessment models focused on business aspects

Authors of Model	Criteria
Doering and Parayre, 2000[a]	Competitiveness criteria
	Strategic criteria
	Marketing criteria
	Criteria relating to the use of the technology
Hsu, Tzeng, and Shyu, 2003[b]	Innovation criteria
	Competitiveness criteria
	Criteria relating to the experience of the supplier organisation
	Marketing criteria
	Criteria relating to the use of the technology
De Coster and Butler, 2005[c]	Competitiveness criteri
	Criteria relating to the experience of the supplier organisation
	Marketing criteria
	Criteria relating to the use of the technology
Jolly, 2005[d]	Competitiveness criteria
	Criteria relating to the experience of the supplier organisation
Chen, Chung, and Wei, 2006[e]	Criteria relating to the experience of the supplier organisation
Łunarski, 2009[f]	Competitiveness criteria
Lucheng, Xin, and Wenguang, 2010[g]	Competitiveness criteria
	Marketing criteria
	Criteria relating to the use of the technology
Shen, Lin, and Tzeng, 2011[h]	Innovation criteria
	Competitiveness criteria
	Criteria relating to the relevance of the technology for the supplier organisation
	Criteria relating to the use of the technology

[a] D.S. Doering, R. Parayre, *Identification and assessment of emerging technology*, [in:] G.S. Day, P.J.H. Schoemaker, R.E. Gunther (eds.), *Wharton on managing emerging technologies*, John Wiley & Sons, Inc., New York 2000, pp. 75–98.
[b] Y.G. Hsu, G.H. Tzeng, J.Z. Shyu, *Fuzzy multiple criteria selection of government – sponsored frontier technology R&D projects*, "R&D Management" 2003, vol. 5(33), pp. 539–551.
[c] R. De Coster, C. Butler, *Assessment of proposals for new technology ventures in the UK: characteristics of university spin-off companies*, "Technovation" 2005, vol. 25(5), pp. 535–543.
[d] D.R. Jolly, *The issue of weightings in technology portfolio management*, "Technovation" 2003, vol. 23(5), pp. 383–391.
[e] Ch.J. Chen, M.Ch. Chung, Ch.H. Wei, *Government policy of technology selection for advanced traveller information systems*, "R&D Management" 2006, vol. 4(36), pp. 439–450.
[f] J. Łunarski, *Zarządzanie technologiami. Ocena i doskonalenie*, Wydawnictwo Politechniki Rzeszowskiej, Rzeszów 2009.
[g] X. Lucheng, L. Xin, L. Wenguang, *Research on emerging technology selection and assessment by technology foresight and fuzzy consistent matrix*, "Foresight" 2010, vol. 2(12), pp. 77–89.
[h] Y.Ch. Shen, G.T.R. Lin, G.H. Tzeng, *Combined DEMATEL techniques with novel MCDM for the organic light emitting diode technology selection*, "Expert Systems with Applications" 2011, vol. 38(3), pp. 1468–1481.

Source: own elaboration in K. Klincewicz, A. Manikowski, *Ocena, rankingowanie i ocena technologii*, Wydawnictwo Naukowe Wydziału Zarządzania Uniwersytetu Warszawskiego, Warszawa 2013, pp. 78–79.

Based on the literature analysis on technology assessment models, the model presented in Figure 2.5 proposed by Doering and Parayre[312], consisting of four stages shown in Table 2.14, was used ultimately to achieve the goals of the scientific monograph because it is iterative and allows for market and technology exploration given the resources and capabilities of the SMART enterprise.

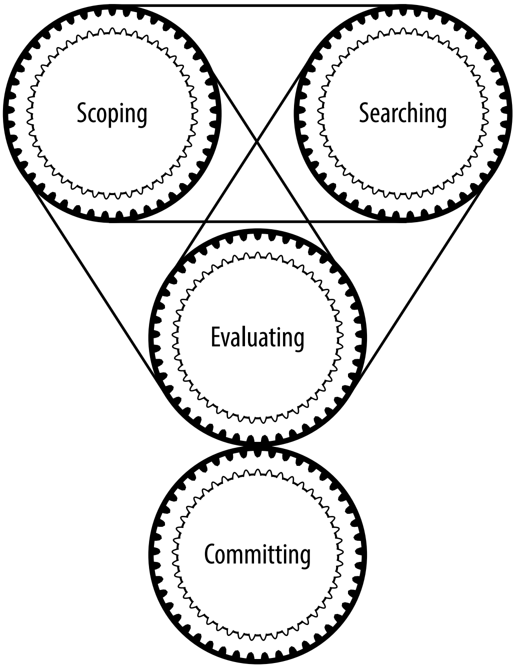

Figure 2.5. The Technology Assessment Process

Source: own elaboration based on D.S. Doering, R. Parayre, *Identification…*, p. 78.

The model was adapted to the proposed proprietary classification by indicating the assessment areas presented in Table 2.15 for each level of technological advantage of the SMART enterprise. Table 2.15 is divided into four main sections scoping, searching, evaluating and committing. Each section presents assessment areas, referring to characteristics of a particular assessment stage. The first section, scoping, focuses on assessing the technology a SMART enterprise owns, the R&D activities it conducts, and the suitability of its workforce to the assumed technological requirements. It also includes an analysis of the potential of currently used technologies in the SMART enterprise concerning market competitors. The second section, searching, focuses on looking for new technology sources inside and outside the enterprise. It also includes a market analysis

312 D.S. Doering, R. Parayre, *Identification…*

regarding the availability of new technologies. Attention is also paid to patent analysis and establishing cooperation with the creators of new technologies to strengthen the design staff. Monitoring other competitors for the creation and possible introduction of new technologies is also assessed, including monitoring parallel discovery or convergence, confirmation knowledge networks, conducting competitive intelligence, and knowledge and information capture. The third section, evaluating, relates directly to the assessment of technology potential analysis from the point of view of the current market, relation to enterprise strategy, required investments, technology commercialisation and expected return on investment. An assessment of risk profiling and the impact of technology on implemented product innovations and business processes are also considered. The final fourth section, committing, assesses the enterprise's implementation of an appropriate approach to implementing new technologies. Approaches such as watch and wait, position and learn, sense and follow, believe and lead have been proposed.

Table 2.14. Stages of the technology assessment process

Technology assessment process stages	Role definition
Scoping	Managers establish the scope and domain of the technology search based on the capabilities of the SMART enterprise and the potential threat or opportunity from the technology. This scope will be continually changing as more is learned about SMART enterprise and technology.
Searching	The SMART enterprise must determine the information and technology sources to monitor, the procedures to follow, and the organisational arrangements that will allow it to screen technologies and search for signals of both emergent technology and its commercial viability.
Evaluating	Candidate technologies must be identified, prioritised, and evaluated against the SMART enterprise's technical capabilities, the target market's needs, and the SMART enterprise's competitive opportunities. Technology development and market entry plan must be drafted, and the financial, competitive, and organisations impacts of the new technologies analysed.
Committing	The first three steps above are used to determine whether to pursue a particular technology. This fourth step addresses how to pursue it by making a strategic commitment to the new technology in the form of a particular strategic posture.

Source: own elaboration in D.S. Doering, R. Parayre, *Identification…*, pp. 77–78.

The technology assessment process has been chosen as a base to construct the tool to determine the level of technological advantage a given SMART enterprise possesses. Depending on the level of technological advantage, the conditions required of the SMART enterprise in question are highlighted in Table 2.15, as described earlier in subchapter 2.4. It will make it possible to check the technology alignment of the SMART enterprise to confirm that the high level of technological advantage determines the level of gained competitive advantage in the age of Industry 4.0 by the SMART enterprise. Furthermore, the proposed tool for assessing the level of technology advantage presented in Table 2.15 reflects the considerations about key conditions mentioned in subchapter 2.3, such as technological innovation capability, technology commercialisation capability, technology transfer performance and SMART enterprise's technological capacity.

Table 2.15. Tool for assessing the level of technological advantage

List of conditions	Level of technological advantage				
X – REQUIRED	1st	2nd	3rd	4th	5th
Scoping					
Possession of basic technologies	X	X	X	X	X
Possession of core technologies	–	–	X	X	X
Possession of emerging technologies	–	–	–	-	X
Conducting R&D activity	–	–	–	X	X
Development of R&D infrastructure	–	–	–	X	X
Investment in R&D activity	–	–	X	X	X
Development of R&D employees	–	–	-	X	X
Cooperation with external R&D centres, e.g. universities	–	–	X	X	X
Management competence to create new technologies	–	–	X	X	X
Management's willingness to bear the risks arising from the creation of new technologies	–	–	X	X	X
Competence of R&D employees in the creation of new technology	–	–	–	X	X
Adequate level of the technological potential of the enterprise for the creation of new technologies	–	–	X	X	X
The financial capacity of the enterprise to create and develop new technologies	–	–	X	X	X
Knowledge of technologies currently used by competing enterprises	–	X	X	X	X
Cooperation with suppliers	X	X	X	X	X
Cooperation with customers	X	X	X	X	X
Cooperation with investors	X	X	X	X	X
Searching					
Management searches for sources of new technology within the enterprise	–	X	X	X	X
Search for external sources of new technology (e.g. analysis of public technology licences, analysis of technical and industry literature, analysis of patents and literature citations)	–	X	X	X	X
Market analysis for new technologies available for current use in the enterprise	X	X	X	X	X
Market analysis for new technologies available for future use in the enterprise	X	X	X	X	X
Establishment of cooperation with external originators of new technologies	–	X	X	X	X
Searching for new employees for the creation and implementation of new technologies	–	X	X	X	X
Monitoring the behaviour of competitors concerning the creation and implementation of new technologies	–	X	X	X	X

List of conditions	Level of technological advantage				
Evaluating					
Ability to assess technological potential from a market perspective	X	X	X	X	X
Analysis and assessment of technological potential from the point of view of the relationship with corporate strategy	X	X	X	X	X
Analysis and assessment of technological potential from the point of view of necessary investments	–	X	X	X	X
Analysis and assessment of technological potential from the point of view of the possibility of commercialisation of the technology	–	–	X	X	X
Analysis and assessment of technological potential from the point of view of the expected return on investment	–	X	X	X	X
Ability to assess the risk of implementing new technologies	–	X	X	X	X
Ability to assess the impact of technology on implemented product innovations and business processes	–	X	X	X	X
Committing					
Application of the watch and wait[a] approach	–	–	–	X	X
Application of the position and learn[b] approach	–	–	–	X	X
Application of the sense and follow[c] approach	–	–	–	X	X
Application of the believe and lead[d] approach	–	–	–	X	X

[a] Watch and wait – used when a new technology's uncertainty is too great to start researching and developing it. The enterprise waits for developments and creates competitive barriers.
[b] Position and learn – used when the uncertainty associated with new technology is low, allowing it to develop and stop the threat from competitors. The enterprise engages with the new technology creating a more active learning process.
[c] Sense and follow – used when an enterprise completes the process of identifying and evaluating a technology by deciding to invest in new technology. The enterprise has a good chance of becoming a market leader while pursuing an active commercialisation strategy.
[d] Believe and lead – used when new technology opportunities are auspicious, and an enterprise can fully commit its resources to commercialise the emerging technology. The enterprise makes a decision based on the intuition and experience of technology leaders at the cutting edge of technology.

Source: own elaboration in D.S. Doering, R. Parayre, *Identification*… based on R.A. Burgelman, C.M. Christensen, S.C. Wheelwright, *Strategic Management of technology and innovation*, McGraw-Hill Irvin, New York 2004; R. Osiadacz, *Proces audytu technologicznego w przedsiębiorstwach*, PARP, Wrocław 2011, pp. 71–88; K. Klincewicz, A. Manikowski, *Ocena, rankingowanie*…, pp. 37–79; M. Ratajczak-Mrozek, *Sieci biznesowe a przewaga konkurencyjna przedsiębiorstw zaawansowanych technologii na rynkach zagranicznych*, Wydawnictwo Uniwersytetu Ekonomicznego w Poznaniu, Poznań 2010, pp. 77–109.

To determine the level of technological advantage, the Synthetic Indicator of the Level of Technological Advantage (SILTA) was created using the tool presented in Table 2.15. The indicator is the sum of the points obtained by the enterprise in the following assessed areas: scoping, searching, evaluating and committing. Due to the varying importance of the conditions for building technological advantage in individual areas resulting from the literature analysis, they were given the corresponding weights presented in Table 2.16.

Table 2.16. Tool for assessing the level of technological advantage (number of points with assumed weights)

List of conditions	Maximum number of points	Weight	Maximum possible number of points with weights
Scoping			
Possession of basic technologies	5	1	5
Possession of core technologies	5	2	10
Possession of emerging technologies	5	3	15
Conducting R&D activity	5	0.6	3
Development of R&D infrastructure	5	0.6	3
Investment in R&D activity	5	0.6	3
Development of R&D employees	5	0.6	3
Cooperation with external R&D centres, e.g. universities	5	0.6	3
Management competence to create new technologies	5	0.4	2
Management's willingness to bear the risks arising from the creation of new technologies	5	0.4	2
Competence of R&D employees in the creation of new technology	5	0.6	3
Adequate level of the technological potential of the enterprise for the creation of new technologies	5	0.4	2
The financial capacity of the enterprise to create and develop new technologies	5	0.4	2
Knowledge of technologies currently used by competing enterprises	5	0.4	2
Cooperation with suppliers	5	0.4	2
Cooperation with customers	5	0.4	2
Cooperation with investors	5	0.4	2
Maximum number of points for section 1:			**64**
Searching			
Management searches for sources of new technology within the enterprise	5	0.4	2
Search for external sources of new technology (e.g. analysis of public technology licences, analysis of technical and industry literature, analysis of patents and literature citations)	5	0.4	2
Market analysis for new technologies available for current use in the enterprise	5	0.4	2
Market analysis for new technologies available for future use in the enterprise	5	0.4	2
Establishment of cooperation with external originators of new technologies	5	0.4	2

List of conditions	Maximum number of points	Weight	Maximum possible number of points with weights
Searching for new employees for the creation and implementation of new technologies	5	0.4	2
Monitoring the behaviour of competitors concerning the creation and implementation of new technologies	5	0.4	2
Maximum number of points for section 2:			**14**
Evaluating			
Ability to assess technological potential from a market perspective	5	0.4	2
Analysis and assessment of technological potential from the point of view of the relationship with corporate strategy	5	0.4	2
Analysis and assessment of technological potential from the point of view of necessary investments	5	0.4	2
Analysis and assessment of technological potential from the point of view of the possibility of commercialisation of the technology	5	0.4	2
Analysis and assessment of technological potential from the point of view of the expected return on investment	5	0.4	2
Ability to assess the risk of implementing new technologies	5	0.4	2
Ability to assess the impact of technology on implemented product innovations and business processes	5	0.4	2
Maximum number of points for section 3:			**14**
Committing			
Application of the watch and wait approach	5	0.4	2
Application of the position and learn approach	5	0.4	2
Application of the sense and follow approach	5	0.4	2
Application of the believe and lead approach	5	0.4	2
Maximum number of points for section 4:			**8**
Total number of points for all sections			**100**

Source: own elaboration.

As in technological advantage, the type of technology used is crucial for determining its appropriate level in the scoping section. The following weights were given to technologies: basic (weighting 1), core (weighting 2) and emerging (weighting 3), which had a decisive impact on the largest share of the first area in the overall assessment. It was followed by an equal weighting of 0.6 for forms of R&D activity, which are also a significant part of the technological advantage. For the remaining conditions, a weight of 0.4 was set (except for the competence of R&D employees in the creation of new technology, for which a weight of 0.6 was selected due to the link with R&D

conditions). An enterprise could obtain a maximum of 64 points in the first assessment area, 14 points each in the second and third areas and 8 points in the fourth area (see Table 2.16). The maximum an enterprise could obtain was 100 points. If an enterprise did not use core and emerging technologies but only basic technologies, the points from the boxes corresponding to the second level of technological advantage were added up (see Table 2.15). If basic and core technologies were used and no emerging technologies were used, the points from the boxes corresponding to the fourth level of technological advantage were added up (see Table 2.15). If basic, core and emerging technologies were used, the points from the boxes corresponding to the fifth level of technological advantage were summed (see Table 2.15). A scoring assessment was proposed to identify at which level of technological advantage an enterprise is located. It is presented in Table 2.17, where the maximum value in a given range was calculated based on the maximum number of points to be obtained summed from the required fields (see Table 2.15) for a given level of technological advantage.

Table 2.17. Required number of points for levels of technological advantage

Level of technological advantage	Interval of points
1	5–19
2	20–39
3	40–65
4	66–85
5	86–100

Source: own elaboration.

For the empirical use of the above concept, a tool based on it was designed to determine a SMART enterprise's current level of technological advantage in the age of Industry 4.0 (Appendix 2). It will form part of the empirical research process to achieve the thesis objectives.

3. Research methodology and characteristics of the researched SMART enterprises

3.1. Characteristics of the automotive industry in Poland

Due to the thematic scope of the scientific monograph, which is mainly based on technological aspects of the age of Industry 4.0, enterprises from the automotive industry operating in Poland were selected for empirical verification of theoretical analyses. SMART enterprises have a significant share in this industry, making it a fascinating research object. Considering the technological conditions, a large part of the automotive industry is already automated and ready to adopt the solutions of the age of Industry 4.0. The specifics and requirements of the age of Industry 4.0 direct the automotive industry towards intelligent and flexible production, allowing it to adapt to the dynamically changing needs of customers. The automotive industry is one of the pillars of the Polish economy (Poland is considered one of the largest automotive regions in Europe) and is one of the most automated industries in the world[313]. To meet the ever-increasing demands of this industry, enterprises in this sector must have guaranteed flexibility in their production lines, supported by the highest possible degree of automation. However, in SMART, robotic and automated enterprises, the human being is still the most crucial factor, and the latest technological developments are aimed at their safety and comfort. It, in turn, translates into greater production efficiency, including less production downtime[314]. Today, technologies based on digitisation and communication are used on a large scale in the automotive industry, making it possible to build a significant advantage over competitors. It is also worth mentioning non-technological aspects, such as appropriate resources, which have also changed significantly with the entry of the age of Industry 4.0 solutions into the industry[315]. At the same time, non-technological conditions of the development of the analysed industry in Poland substantially limit its possibilities. The most critical challenges for the automotive industry in Poland, from the point of view of both manufacturers and distributors, are the political and economic situation in Poland and abroad, new legal regulations, labour costs, exchange rate volatility and access to qualified technical staff. As far as the crisis

313 *Polski przemysł: motoryzacja*, 2018, https://controlengineering.pl/polski-przemysl-motoryzacja/ (accessed: 3.11.2022).

314 *Czwarta rewolucja przemysłowa w branży Automotive*, 2017, https://zrobotyzowany.pl/informacje/publikacje/2815/czwarta-rewolucja-przemyslowa-w-branzy-automotive (accessed: 3.11.2022).

315 *Przemysł 4.0 – Jak wygląda czwarta rewolucja przemysłowa w Automotive?*, 2020, https://knaufautomotive.com/pl/lancuch-dostaw-i-przemysl-4-0-w-przemysle-motoryzacyjnym/ (accessed: 3.11.2022).

concerning the availability of semiconductors is concerned, it still has a powerful impact on the current way of doing things, which has led to a diversification of supply routes, investments by automotive enterprises in their component production capacity and closer or direct cooperation with component manufacturers[316]. Due to the use of technology and non-technological aspects of the age of Industry 4.0 on a large scale in practice, automotive production enterprises were chosen as the object of the study.

As far as the structure of automotive production enterprises in Poland is concerned, it can be divided into five main divisions of the PKD (Polish Classification of Activities):

- Division 22 – Manufacture of rubber and plastic products,
- Division 27 – Manufacture of electrical equipment,
- Division 28 – Manufacture of machinery and equipment n.e.c.,
- Division 29 – Manufacture of motor vehicles, trailers and semi-trailers,
- Division 30 – Manufacture of other transport equipment.

Within the divisions mentioned above, Poland has 720 enterprises[317] (small, medium and large). Table 3.1 shows the distribution of selected automotive production enterprises by PKD subclass. The most numerous are the subclasses Manufacture of other parts and accessories for motor vehicles excluding motorcycles (29.32.Z) and Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers (29.20.Z). The least numerous subclasses are Manufacture of cars (29.10.B), Manufacture of motor vehicles for the transport of goods (29.10.D), Manufacture of motorcycles (30.91.Z), Manufacture of engines for motor vehicles (excluding motorcycles) and for agricultural tractors (29.10.A) and Manufacture of military fighting vehicles (30.40.Z)[318].

Table 3.2 shows the distribution of selected automotive production enterprises by voivodeship, which shows that the most significant number of enterprises is in the Slaskie, Mazowieckie, Dolnoslaskie and Wielkopolskie voivodeships and the smallest in the Podlaskie, Opolskie and Warminsko-Mazurskie.

316 *Barometr Nastrojów Menedżerów Branży Motoryzacyjnej PZPM i KPMG 1/2022*, 2022, https://www.pzpm.org.pl/pl/Rynek-motoryzacyjny/Roczniki-i-raporty/Barometr-Nastrojow-Menedzerow-Branzy-Motoryzacyjnej-PZPM-i-KPMG-1-2022 (accessed: 10.10.2022).

317 As of 31.12.2023.

318 Główny Urząd Statystyczny, *Kwartalna informacja o podmiotach gospodarki narodowej w rejestrze REGON rok 2021*, 2022, https://stat.gov.pl/obszary-tematyczne/podmioty-gospodarcze-wyniki-finansowe/zmiany-strukturalne-grup-podmiotow/kwartalna-informacja-o-podmiotach-gospodarki-narodowej-w-rejestrze-regon-rok-2021,7,9.html (accessed: 15.01.2022).

Table 3.1. Distribution of selected automotive production enterprises by PKD subclass (as of 31.12.2021)

PKD subclasses	Small enterprises	Medium enterprises	Large enterprises	Sum
Manufacture of other parts and accessories for motor vehicles excluding motorcycles (29.32.Z)	153	94	69	**316**
Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers (29.20.Z)	73	47	6	**126**
Manufacture of electric motors, generators and transformers (27.11.Z)	42	22	13	77
Manufacture of bearings, gears, gearing and driving elements (28.15.Z)	23	26	7	56
Manufacture of electrical and electronic equipment for motor vehicles (29.31.Z)	24	12	13	49
Manufacture of batteries and accumulators (27.20.Z)	13	9	4	26
Manufacture of rubber tyres and tubes; retreading and rebuilding of rubber tyres (22.11.Z)	9	3	7	19
Manufacture of other motor vehicles excluding motorcycles (29.10.E)	5	5	3	13
Manufacture of buses (29.10.C)	8	0	4	12
Manufacture of cars (29.10.B)	6	0	2	**8**
Manufacture of motor vehicles for the transport of goods (29.10.D)	4	1	2	**7**
Manufacture of motorcycles (30.91.Z)	5	0	0	**5**
Manufacture of engines for motor vehicles (excluding motorcycles) and for agricultural tractors (29.10.A)	0	2	2	**4**
Manufacture of military fighting vehicles (30.40.Z)	0	0	2	**2**
Total	**365**	**221**	**134**	**720**

Source: own elaboration based on Główny Urząd Statystyczny, *Kwartalna informacja o podmiotach gospodarki narodowej w rejestrze REGON rok 2021*, 2022, https://stat.gov.pl/obszary-tematyczne/podmioty-gospodarcze-wyniki-finansowe/zmiany-strukturalne-grup-podmiotow/kwartalna-informacja-o-podmiotach-gospodarki-narodowej-w-rejestrze-regon-rok-2021,7,9.html (accessed: 15.01.2022).

Table 3.2. Distribution of selected automotive production enterprises by voivodships (as of 31.12.2021)

Voivodeship	Small enterprises	Medium enterprises	Large enterprises	Sum
Slaskie	66	48	40	**154**
Mazowieckie	67	31	3	**101**
Dolnoslaskie	42	26	24	**92**
Wielkopolskie	46	21	21	**88**
Lodzkie	18	17	6	41
Podkarpackie	18	10	8	36

Voivodeship	Small enterprises	Medium enterprises	Large enterprises	Sum
Malopolskie	14	13	6	33
Kujawsko-Pomorskie	17	6	2	25
Zachodniopomorskie	10	11	4	25
Lubuskie	13	6	4	23
Pomorskie	11	8	4	23
Swietokrzyskie	11	7	3	21
Lubelskie	9	7	3	19
Opolskie	5	5	4	**14**
Warminsko-Mazurskie	8	4	1	**13**
Podlaskie	10	1	1	**12**
Total	**365**	**221**	**134**	**720**

Source: own elaboration based on Główny Urząd Statystyczny, *Kwartalna informacja…*

The research covered 2019–2021, in which the technologies of the age of Industry 4.0 were no longer new and were widely available to enterprises, including automotive production. From 2019 onwards, despite considerable changes in the automotive market due to pandemics, shortages of components, e.g. semiconductors, rising labour costs, rising production costs, the political and economic situation, both at home and abroad, leading entrepreneurs invested in research into new technologies and the expansion of factories[319]. In the present and future of the automotive industry in Poland, it is worth mentioning the changing characteristics of the drives used in vehicles. Currently, combustion and hybrid drives have a significant advantage on the market. It is expected that soon, most drives will be electric or hydrogen. Internal combustion drives are likely to be converted to plug-in hybrids. This significant change opens up new opportunities and challenges for producing increasingly sophisticated components requiring newer and newer production technologies. Introducing solutions and differentiated technologies in the age of Industry 4.0 will support the efficiency and quality of the associated production processes, minimising the risk of error or deviation from the assumed production standard. Introducing new production technologies will make it easier for Polish manufacturers in this industry to catch up with European and global competitors. Therefore, the future for the automotive industry in Poland lies in the technological solutions of the age of Industry 4.0. Production enterprises in this industry must understand their significance and the processes accompanying their effective and efficient implementation as soon as possible. In a SMART world environment, this is the only way they can more consciously support and shape their competitiveness and the accompanying competitive advantage.

319 Polski Związek Przemysłu Motoryzacyjnego, *Rocznik PZPM – Raport branży motoryzacyjnej 2023/2024*, 2024, https://www.pzpm.org.pl/pl/Rynek-motoryzacyjny/Roczniki-i-raporty/Rocznik-PZPM-Raport-branzy-motoryzacyjnej-2021-2022 (accessed: 10.10.2022).

3.2. Research objectives, hypotheses and procedure

The research procedure undertaken for realising the scientific monograph objectives was divided into three stages, and the structure of the process as an ordered sequence of activities is presented in Figure 3.1. In the first stage, a critical analysis of Polish and foreign literature and the results of secondary research were carried out concerning the management of an organisation in the age of Industry 4.0, specific requirements of Industry 4.0, and building technological advantage and competitive advantage. On this basis, cognitive gaps were identified that justify researching the identification of conditions for building technological advantage in SMART enterprises in the age of Industry 4.0.

The perceived **theoretical gap** resulted from needing to define the concepts of technological potential and technological advantage as components of building an enterprise's competitive advantage. In the literature, a comprehensive analysis of the concept of technological advantage of enterprises is significantly rarely carried out, even more rarely with a subsequent attempt to define its impact on building competitive advantage of enterprises, especially those with SMART characteristics.

The diagnosed **empirical gap** is related to the need for more research on the analysis and evaluation of the technological advantage of enterprises as a determinant of building the competitive advantage of SMART enterprises. The research is fragmented and mainly relates to identifying factors of a generally defined competitive advantage.

The **methodological gap** is due to the need for more operationalisation and standardised methods for measuring enterprises' technological potential and technological advantage, especially those with SMART characteristics.

A **practical gap** was also observed, indicating the need for more business practice recommendations to improve an enterprise's competitiveness, especially those with SMART characteristics, through appropriately targeted enhancement of their technological potential and building of technological advantage.

In an attempt to fill the above cognitive gaps, the main objective of the scientific monograph was identification and characterisation the conditions of technological advantage of SMART enterprises and to assess the dependence of the level of competitive advantage on the level of technological advantage of these enterprises (MO).

The following specific objectives are subordinated to the realisation of the main objective thus formulated:
- O1: Evaluation of the key requirements for SMART enterprises by the age of Industry 4.0 (realised in chapter 1).
- O2: Identification and systematisation of the conditions determining the building of technological advantage in SMART enterprises (realised in chapter 2).

- O3: Creation and operationalisation of a research tool to assess the level of technological advantage of SMART enterprises (realised in chapter 2).
- O4: Identification of the relationship between degree of familiarity and scope of application of the requirements of the age of Industry 4.0 and the level of the technological potential of SMART enterprises (realised in chapter 4).
- O5: Identification of the relationship between the level of technological potential development and the level of technological advantage of SMART enterprises (realised in chapter 4).
- O6: Identification of the relationship between the level of technological advantage and the level of competitive advantage of SMART enterprises (realised in chapter 4).
- O7: Development of a procedure to follow in the process of building technological advantage in SMART enterprises (realised in chapter 4).

For the objectives thus set, research problems were formulated, expressed in the form of the following questions:

- Q1: What are the key requirements of the age of Industry 4.0 for the successful operation of SMART enterprises?
- Q2: What conditions determine the building of the technological advantage of SMART enterprises?
- Q3: How should the level of technological advantage in SMART enterprises be assessed?
- Q4: How do degree of familiarity and scope of application of the requirements of the age of Industry 4.0 affect the level of technological potential in SMART enterprises?
- Q5: How does the level of technological potential development of SMART enterprises affect their level of technological advantage?
- Q6: How does the level of technological advantage affect the level of competitive advantage of SMART enterprises?
- Q7: How to build the technological advantage of SMART enterprises?

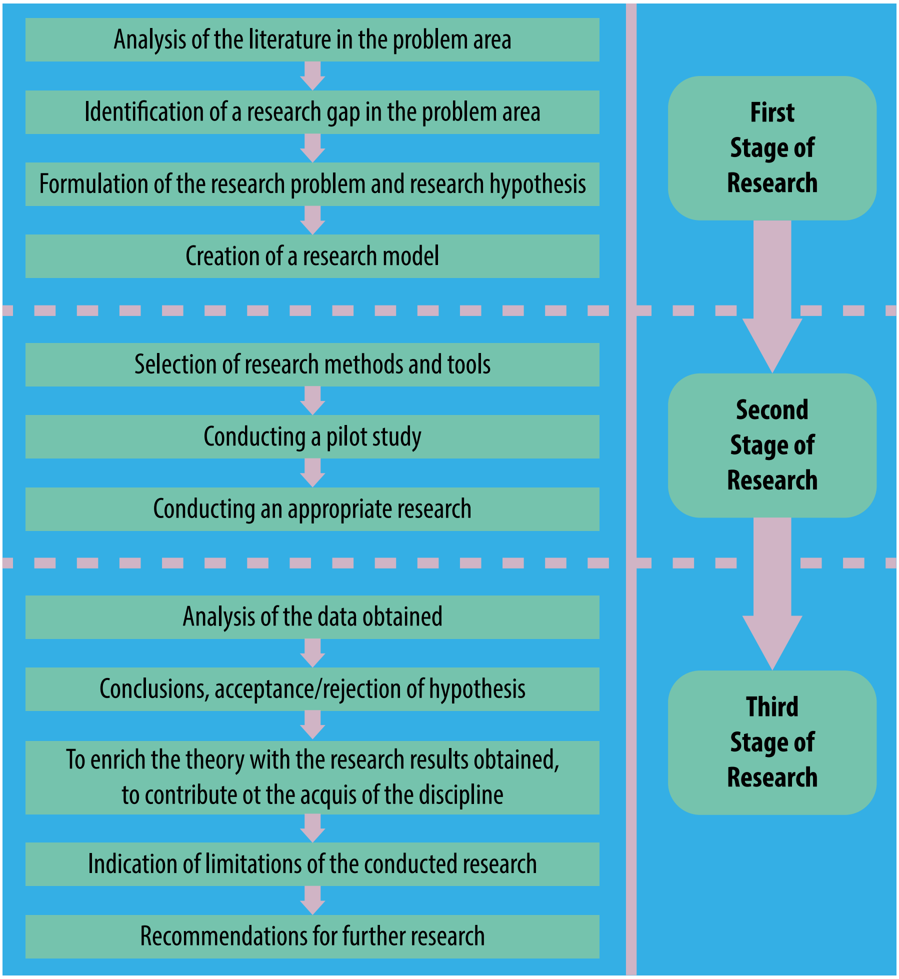

Figure 3.1. Stages in the research procedure

Source: own elaboration based on A. Zakrzewska-Bielawska, *Strategie rozwoju przedsiębiorstw. Nowe spojrzenie*, Polskie Wydawnictwo Ekonomiczne, Warszawa 2018, p. 103; Z. Chyba, *Przedsiębiorczość technologiczna…*, p. 136; W. Dyduch, *Ilościowe badanie i operacjonalizacja zjawisk w naukach o zarządzaniu*, [in:] W. Czakon (ed.), *Podstawy metodologii badań w naukach o zarządzaniu*, Oficyna a Wolters Kluwer business, Warszawa 2011; M. Baran, *Struktura procesu badawczego*, [in:] Ł. Sułkowski, R. Lenart-Gansiniec, K. Kolasińska-Morawska (eds.), *Metody badań ilościowych w zarządzaniu*, Wydawnictwo Społecznej Akademii Nauk, Łódź 2021, p. 28.

Bearing in mind the objectives of the thesis, both main and specific, as well as the research questions posed in the scientific monograph, five underlying theoretical constructs were adopted as the basis for analysis: (1) degree of familiarity with Industry 4.0 requirements, (2) scope of application of Industry 4.0 requirements, (3) technological potential, (4) level of technological advantage and (5) level of competitive advantage.

These were used to formulate the main hypothesis and accompanying specific scientific monograph hypotheses.

- MH. The ability to form a technological advantage in the age of Industry 4.0 increases the effectiveness of the process of building SMART enterprises' competitive advantage.

  To clarify the main hypothesis, four specific hypotheses were also adopted:
- H1: Degree of familiarity with the requirements of the age of Industry 4.0 supports the development of the technological potential of SMART enterprises.
- H2: Application of solutions compliant with the requirements of the age of Industry 4.0 increases the development level of SMART enterprises' technological potential.
- H3: The higher the level of technological potential development, the higher the level of technological advantage obtained by SMART enterprises in the age of Industry 4.0.
- H4: The higher the level of technological advantage, the higher the level of competitive advantage gained by SMART enterprises in the age of Industry 4.0.

Based on the extracted constructs and the relationships indicated between them, a research model was formulated as the culmination of the first stage of the research procedure (see Figure 3.2).

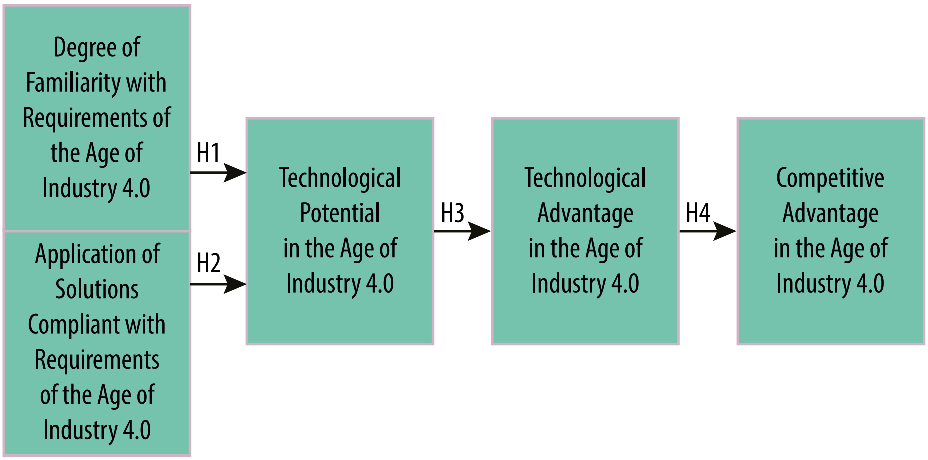

Figure 3.2. Research model

Source: own elaboration.

In the second stage of the research, the focus was on selecting research methods and tools, and a pilot study and appropriate research were carried out. In the adopted research procedure, quantitative research was designed and implemented using surveys. The data collection process used the multi-mode method[320], which combines

320 A. Zakrzewska-Bielawska, *Strategie rozwoju*…, p. 104.

two survey techniques, CAWI and CATI. The main advantages of the CAWI technique were the possibility to survey large groups of respondents, the relatively short time of data collection, the anonymity of the research and the possibility of presenting multimedia materials. On the other hand, the main problems identified were: problems with identifying the respondent's identity and the lack of opportunity for direct contact with the respondent. The advantages of the CATI technique were identified as constant monitoring of the survey and the quality of the data collected, control over the respondent's identity, relatively short time of data collection, direct coding of the information obtained in the computer and standardisation of the survey. At the same time, the disadvantages were the inability to present multimedia materials to the respondents and to visualise the questionnaire[321]. By combining these two techniques, applying the multi-mode method made it possible to eliminate their disadvantages, translating into increased data quality, significantly reducing the risk of errors, and improved data reliability[322].

The research tool was a structured and standardised survey questionnaire (see Appendix 1), which was developed based on the constructs of the research model. The questionnaire consisted of a metric and a main part. The metric included four questions to characterise the enterprises surveyed by age, size measured by number of employees, type of business and dominant market area. The main part of the questionnaire was divided into four thematic sections. The first one concerned the degree of familiarity and scope of application of the age of Industry 4.0 requirements by a SMART enterprise regarding technology and non-technological solutions – four questions in total. The second section consisted of one question on the components of the technological potential of the enterprise under study. The third section contained six questions to assess the enterprise's technological advantage level. The last section had three questions concerning the enterprise's competitive advantage level. The questionnaire was dominated by questions with an ordinal scale – a five-point Likert scale. The choice of this scale was determined primarily by the speed of completing the questionnaire and the efficient data analysis process[323]. When creating the scale, recommendations for the construction of measurement scales were taken into account[324], i.e. a helpful measurement scale should be simple and provide high-quality data, which results in its reliability. Furthermore, the scale should be characterised by univariant validity, i.e. all scale items can be placed on a continuum relating to one concept.

321 *Ibidem*, p. 105.

322 *Ibidem*, pp. 105–106.

323 A. Walecka, *Kapitał relacyjny a odporność przedsiębiorstwa na zjawiska kryzysowe*, Wydawnictwo Politechniki Łódzkiej, Łódź 2019, p. 130.

324 Broader: D. Węziak-Białowolska, *Operacjonalizacja i skalowanie w ilościowych badaniach społecznych*, "ISiD Working Papers" 2011, no. 16.

The respondents in the survey were owners, enterprise executives and R&D division managers. Such respondents who had, in addition to general knowledge of the enterprise's operations, knowledge of aspects of technological know-how in production processes were selected. The survey process itself and the piloting were outsourced to an external company. A pilot study was carried out on a sample of 10 automotive manufacturing enterprises selected at random to verify the questionnaire and make appropriate adjustments to it. One interview's duration and the questions' logic were also checked. Following the pilot study, the research hypotheses were refined, and the research procedure was refined and planned[325]. This stage culminated in the selection of the sample and the conduct of the appropriate research.

In the third stage of the research, the data obtained during the research process was analysed using mixed methods[326] with a quantitative and qualitative perspective[327] in the area of methods of analysis[328]. In the case of quantitative analysis, advanced statistical tools were used, described in detail in the following subchapter of the thesis, which allowed for the conclusion of acceptance, rejection of research hypotheses and the formulation of generalisations. On the other hand, the qualitative analysis of the data obtained during the research process gave the possibility of a detailed characterisation of the selected 20 cases of enterprises, i.e. four representing each level of technological advantage, which turned out to be crucial for the development of a procedure to follow in the process of building the technological advantage of the SMART enterprise. The use of a mixed approach, i.e. quantitative and qualitative perspectives on data analysis, provided a complete picture of the required conditions for a given level of technological advantage (described in Table 2.15 in subchapter 2.4), which made it possible to answer the formulated research questions: "How should the level of technological advantage in SMART enterprises be assessed?".

3.3. Applied methods of statistical analysis

Several statistical measures and tools were selected according to the research sample type and how the variables were measured and used to organise and analyse the data obtained during the study (see Table 3.3). All analyses were carried out using the IBM

325 M. Baran, *Struktura procesu…*, p. 40.

326 Ł. Sułkowski, R. Lenart-Gansiniec, *Epistemologia, metodologia i metody badań w naukach o zarządzaniu i jakości*, Wydawnictwo Społecznej Akademii Nauk, Łódź 2021, p. 327.

327 A. Tashakkori, J.W. Creswell, *Editorial: Exploring the Nature of Research Questions in Mixed Methods Research*, "Journal of Mixed Methods Research" 2007, vol. 1(3), pp. 207–211; B. Glinka, W. Czakon, *Podstawy badań jakościowych*, Polskie Wydawnictwo Ekonomiczne, Warszawa 2021, pp. 30–31.

328 Broader: B.J. Gabryś, *Mixed methods w procesie łagodzenia napięć metodologicznych w naukach o zarządzaniu*, Wydawnictwo Uniwersytetu Ekonomicznego we Wrocławiu, Wrocław 2016, pp. 128–136.

SPSS Statistics 28 package. The variation between populations, as well as the relationships between the study variables, were considered statistically significant if the test probability $p < \alpha$, with an assumed significance level of $\alpha = 0.05$.

The variables were measured on an ordinal scale (five-point Likert scale) and a nominal scale primarily for data characterising the enterprise and its competitive position.

Table 3.3. Statistical measures and tools used to analyse the obtained data

Type of analysis	Measure/statistical tool	Application
Preliminary data analysis	Structure (frequency) indicators and descriptive statistics	Entire questionnaire
Comparative analysis	ANOVA, Shapiro-Wilk test, Kruskal-Wallis test, Levene's test, Welch's test, post-hoc tests, Bonferroni test, Tamhane's T2 test	Entire questionnaire
Dependence analysis	Chi-square test of independence, Fisher's exact test, Spearman's rank correlation coefficient, Kendall's Tau-c coefficient, Pearson's linear correlation coefficient	Specific hypothesis testing
Scale reliability analysis	Cronbach's α coefficient	Variables (statements in the questionnaire) used to measure degree of familiarity with Industry 4.0 requirements, scope of application of Industry 4.0 requirements, technological potential, level of technological advantage, level of competitive advantage

Source: own elaboration.

Structural indicators, and descriptive statistics to determine the distribution of responses for all variables, were used to preliminary analysis of the data obtained during the research process.

For the comparative analysis, we first used analysis of variance (ANOVA – ANalysis Of VAriance), a parametric method used to resolve the existence of differences between means in several (two or more) populations. One-way analysis of variance applies when the dependent variable is measured on a quantitative scale[329] and the independent

329 In research practice, certain variables measured on an ordinal scale can sometimes be treated as quantitative. It applies, for example, to variables for which data are collected using numerical scales with even-looking intervals, e.g. "on a scale of 0 to 10, where 0 means […] and 10 means […] indicate the point that corresponds to your opinion in this regard" – broader: A. Agresti, B. Finlay, *Statistical methods for the social sciences*, Pearson, London 2014. A similar approach is taken for variables measured on a Likert scale (subject to certain conditions, including it should be at least five-point, the distribution of responses should not be strongly symmetrical, and an odd number of options is recommended, taking into account the so-called middle of the scale – cf., e.g. G.H. Lubke, B.O. Muthen, *Applying Multigroup Confirmatory Factor Models for Continuous Outcomes to Likert Scale Data Complicates*

variable is a qualitative/discrete variable (measured on a nominal or ordinal scale). In the terminology adopted in the analysis of variance, the independent variable is called a factor, and its values are called levels.

The analysis of variance uses the F-test. It is a parametric test that requires assumptions about the distribution of the dependent variable in the populations being compared:

- the dependent variable should have a normal distribution in each population being compared,
- the variance of the dependent variable in the compared subpopulations should be homogeneous.

The Shapiro-Wilk test was used to check whether the assumptions for using one-way ANOVA for normal distribution were met[330]. In this test, the hypotheses are of the form: H_0 – the distribution of the dependent variable is normal, H_1 – the distribution of the dependent variable converges to a normal distribution. The distribution of a variable is considered to converge to a normal distribution if $p > \alpha$, and if $p < \alpha$ deviations from the normal distribution are considered. The assumption of homogeneity of variances was tested using Levene's test, which tests the null hypothesis indicating equality of variances. Thus, if Levene's test yields a $p < 0.05$ there are differences between the variances in the groups being compared.

If the assumptions of normality of distribution and homogeneity of variance were met, then one-way analysis of variance (ANOVA) was used for comparisons.

The system of hypotheses in the one-way analysis of variance is as follows:

H_0: $\mu_1 = \mu_2 = \ldots = \mu_k$ (all expected values in the subpopulations are equal),

H_1: $\neg H_0$ (at least two expected values are not equal).

Assuming $\alpha = 0.05$, the conclusions were performed according to the rules:

- If $p < 0.05$, we conclude that there are grounds to reject the null hypothesis and accept the alternative hypothesis. A significant F-test result entitles us to conclude that at least two expected values in the subpopulations differ. In the next step, analyses are undertaken to answer the question of these differences' expected values. Post-hoc tests are used for this purpose.

Meaningful Group Comparisons, "Structural Equation Modeling" 2004, vol. 11(4), pp. 514–534; J. Wiktorowicz, *Międzypokoleniowy transfer wiedzy a wydłużanie okresu aktywności zawodowej*, Wydawnictwo Uniwersytetu Łódzkiego, Łódź 2016. Consequently, one can find in the literature, including textbooks, examples of the application of analysis of variance on ordinal variables treated as quasi-quantitative, with bottom-up and top-down limited ranges and a relatively narrow scale span. It is practised with large samples – M. Rószkiewicz, *Analiza klienta*, SPSS Polska, Kraków 2011, p. 123; A. Agresti, B. Finlay, *Statistical methods…*, p. 371.

330 Broader about the test in studies: W. Szymczak, *Podstawy statystyki dla psycholgów. Podrecznik akademicki*, Difin, Warszawa 2018; J. Wiktorowicz, M.M. Grzelak, K. Grzeszkiewicz-Radulska, *Analiza statystyczna z IBM SPSS Statistics*, Wydawnictwo Uniwersytetu Łódzkiego, Łódź 2020.

- If $p > 0.05$, we conclude that there are no grounds to reject the null hypothesis – the differences between the expected values in the compared subpopulations are not statistically significant.

When the assumption of normality of the distribution of the dependent variable across subpopulations is met, but the dispersion of the results around the means is markedly different (the assumption of homogeneity of variance is not met), a resistant ("strong") version of ANOVA-the Welch test, was used instead of the F-test[331].

If the differences between the expected values for the compared subpopulations are statistically significant ($p < \alpha$), this does not mean that all subpopulations are significantly different, only that at least one is different from the others. The next step is determining which expected values these differences occur, which can be done using post-hoc tests (pairwise multiple comparison tests). In these, the expected values are compared in pairs. The choice of post-hoc test depends on whether the assumption of homogeneity of variances is met – if so, e.g. Bonferroni, Scheffe, Tukey test is used, while with heterogeneous variances – e.g. Tamhane's T2 test[332].

If the assumption of the normality of the distribution of the dependent variable is broken, or if the dependent variable is measured on an ordinal scale, then the non-parametric equivalent of the F-test should be used, i.e. the Kruskal-Wallis H-test[333], in which the values of the dependent variable are replaced by ranks, which consequently makes it possible to compare not the arithmetic mean values of the variable, but the mean ranks. If in the Kruskal-Wallis test $p < \alpha$, it can be concluded that the distribution of the dependent variable in at least one of the subpopulations being compared differs significantly, and otherwise $p > \alpha$ there are no significant differences between the subpopulations being compared from the point of view of the phenomenon under study (the samples come from a population with a similar distribution)[334].

The comparative analysis aimed to identify differences in respondents' answers regarding degree of familiarity and scope of application of the requirements of the age of Industry 4.0 in the surveyed enterprise, the technological potential of the enterprise, the level of technological advantage and competitive advantage concerning the characteristics of the enterprise – size and age.

To analyse the relationships defined in the specific hypotheses between the degree of familiarity of requirements of the age of Industry 4.0 and technological potential

331 Broader about the test in studies: A.D. Aczel, *Statystyka w zarządzaniu*, Wydawnictwo Naukowe PWN, Warszawa 2000 and W. Starzyńska, *Podstawy statystyki*, Wydawnictwo Difin, Warszawa 2009.

332 Broader about this topic in studies: J. Wiktorowicz, M.M. Grzelak, K. Grzeszkiewicz-Radulska, *Analiza statystyczna…*

333 Broader about the test in studies: A.D. Aczel, *Statystyka…*; A. Malarska, *Analiza statystyczna wspomagana programem SPSS*, SPSS Polska, Kraków 2005; W. Szymczak, *Podstawy statystyki…*

334 J. Wiktorowicz, M.M. Grzelak, K. Grzeszkiewicz-Radulska, *Analiza statystyczna…*, pp. 111–112.

(H1), between the scope of application of solutions compliant with requirements of the age of Industry 4.0 and technological potential (H2), between the level of technological potential and the level of technological advantage (H3) and between the level of technological advantage and the level of technological advantage (H4) were used:

- The chi-square test of independence because the variables studied were mainly discrete (measured on a nominal or ordinal scale). The chi-square test compares the two-dimensional empirical distribution of a variable with the theoretical (expected) distribution that would occur if the variables were independent. Assessing the significance of the relationship is based on comparing the empirical counts presented in the contingency table with the theoretical counts. If, in the chi-squad test, p is lower than the accepted cut-off level (5%, which means assuming a significance level of $\alpha = 0.05$, the null hypothesis of independence of the variables should be rejected and the alternative hypothesis accepted. It means that the relationship between the variables is not the result of random error but is statistically significant. The chi-square independence test requires that the expected counts in all cells are greater than or equal to 5. If this assumption was not met, Fisher's exact test was used. This test's hypotheses have the same formulation as in the chi-square independence test. For statistically significant relationships, the strength of the relationship was assessed in the next step using measures of the relationship adapted to the measurement scale of the variables. The following coefficients were used to determine the strength of the relationship between variables characterised by the ordinal level of measurement: the Spearman rank (rho)[335] and Kendall's tau-c[336]. It was assumed that the relationship is: powerful when the value of the coefficient is above 0.9, significant – a value from 0.7 to 0.9, moderate – a value of 0.4 – 0.7, weak – a value below 0.4, and a value of 0 indicates no relationship[337].
- When analysing the relationship between the synthetic indicators: (1) Synthetic Indicator of the Degree of Familiarity with Industry 4.0 Technologies (SIDFI4.0T), (2) Synthetic Indicator of the Degree of Familiarity with Non-Technological Requirements of Industry 4.0 (SIDFNTRI4.0), (3) Synthetic Indicator of the Scope of Application of Industry 4.0 Technologies (SISAI4.0T), (4) Synthetic Indicator of the Scope of Application of Non-Technological Requirements of Industry 4.0 (SISANTRI4. 0), (5) Synthetic Indicator of the Technological Potential (SITP), (6) SILTA, (7) Synthetic Indicator of the Level of Competitive Advantage (SILCA), (8) Current Competitive Position (CCP), the Pearson's linear correlation coefficient (r) was applied due

335 Broader: W. Szymczak, *Podstawy statystyki…* and J. Wiktorowicz, M.M. Grzelak, K. Grzeszkiewicz-Radulska, *Analiza statystyczna…*

336 Broader: B. Ghaliba, *Relationship Between Kendall's tau Correlation and Mutual Information*, "Revista Colombiana de Estadística" 2020, vol. 43(1), pp. 3–20.

337 W. Starzyńska, *Statystyka praktyczna*, Wydawnictwo Naukowe PWN, Warszawa 2020.

to the quantitative level of measurement of these variables, after checking: whether the examined relationship is linear, based on a scatter plot and examining the normality of the distribution of the analysed characteristics in the general population. The value of this indicator is in the range [–1;1]. The higher its absolute value, the stronger the relationship between the analysed variables[338]. It was assumed that the relationship is: powerful when the value of the coefficient is above 0.9, significant – a value from 0.7 to 0.9, moderate – a value of 0.4–0.7, weak – a value below 0.4, and a value of 0 indicates no relationship.

To assess the scale's reliability, Cronbach's alpha coefficient was used, which is based on the correlation coefficients of all survey questions with the overall score of the scale[339]. This statistic, in simple terms, is the mean calculated from the correlation coefficients of all possible halves of the test. The Cronbach's alpha coefficient takes values between 0 and 1; the recommended values are between 0.7 and 0.95. Values below the reference value may indicate, for example, poor intercorrelation between indicators, an insufficient number of questions, and, in the case of too high an indicator, the problem may be too many similar indicators[340]. Reliability was examined for the variables analysed: degree of familiarity with Industry 4.0 requirements, scope of application of Industry 4.0 requirements, level of technological potential, level of technological advantage, and level of competitive advantage (see Table 3.4).

Table 3.4. Reliability analysis for the scales used in the quantitative research

Variable	Cronbach's alpha reliability coefficient
Degree of familiarity with Industry 4.0 requirements	0.91
Scope of application of Industry 4.0 requirements	0.93
Technological potential	0.89
Level of technological advantage	0.92
Level of competitive advantage	0.81

Source: own elaboration.

The Cronbach's alpha reliability coefficient for all analysed variables took values in the range of 0.81–0.93, indicating the large-scale reliability of the research tool.

338 Broader: W. Starzyńska, *Podstawy statystyki…* and J. Wiktorowicz, M.M. Grzelak, K. Grzeszkiewicz-Radulska, *Analiza statystyczna…*

339 Broader: L.J. Cronbach, *Dwa nurty psychologii naukowej*, [in:] J. Brzeziński (ed.), *Metodologia badań psychologicznych. Wybór tekstów*, Wydawnictwo Naukowe PWN, Warszawa 2004, pp. 21–43; W. Czakon, *Podstawy metodologii badań w naukach o zarzadzaniu*, Oficyna a Wolters Kluwer business, Warszawa 2015.

340 P. Klimas, *Skale pomiaru: konstrukcja, walidacja skal nowych versus weryfikacja i adaptacja skal replikowanych*, [in:] Ł. Sułkowski, R. Lenart-Gansiniec, K. Kolasińska-Morawska (eds.), *Metody badań ilościowych w zarządzaniu*, Wydawnictwo Społecznej Akademii Nauk, Łódź 2021, p. 132.

3.4. Sampling and characteristics of the researched enterprises

Appropriate research was conducted in May–June 2022 in small, medium and large automotive production enterprises functionating in Poland using the CAWI and CATI techniques, based on a structured and standardised survey questionnaire developed based on a research model. The survey intentionally eliminated micro-enterprises, in which R&D activity is rarely carried out at all, due to their specific nature characterised by limited resources, especially technological ones. It does not allow for the effective building of technological advantage in the age of Industry 4.0.

The assumption was made to obtain a representative sample, maximally corresponding to the studied population, to generalise the results obtained to the entire population from which it was taken.

The sampling frame was a database of 720 records (365 small, 221 medium and 134 large enterprises) from the REGON National Economy Register from selected subclasses of the PKD section C from the following divisions:
- Division 22 – Manufacture of rubber and plastic products: Manufacture of rubber tyres and tubes; retreading and rebuilding of rubber tyres (22.11.Z),
- Division 27 – Manufacture of electrical equipment: Manufacture of electric motors, generators and transformers (27.11.Z), Manufacture of batteries and accumulators (27.20.Z),
- Division 28 – Manufacture of machinery and equipment n.e.c.: Manufacture of bearings, gears, gearing and driving elements (28.15.Z),
- Division 29 – Manufacture of motor vehicles, trailers and semi-trailers: Manufacture of engines for motor vehicles (excluding motorcycles) and for agricultural tractors (29.10.A), Manufacture of cars (29.10.B), Manufacture of buses (29.10.C), Manufacture of motor vehicles for the transport of goods (29.10.D), Manufacture of other motor vehicles excluding motorcycles (29.10.E), Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers (29.20.Z), Manufacture of electrical and electronic equipment for motor vehicles (29.31.Z), Manufacture of other parts and accessories for motor vehicles excluding motorcycles (29.32.Z),
- Division 30 – Manufacture of other transport equipment: Manufacture of military fighting vehicles (30.40.Z), Manufacture of motorcycles (30.91.Z).

These were all enterprises from selected PKD subclasses of the automotive industry functionating in Poland[341]. The selection of enterprises to participate in the survey was made using the dependent (non-returnable) sampling process applied to finite populations. It consists of the fact that a drawn element of the population is not

341 Główny Urząd Statystyczny, *Kwartalna informacja…*

returned to it so that it appears only once in the sample. It means that after each draw, the size of the population was reduced by 1. From the sampling frame, i.e. a numbered list of all entities comprising the population under study, every 10th record was selected. The sample selection within the surveyed groups (small, medium and large enterprises) was random, i.e. the same probability of being in the sample could be indicated for the individual sampling units that were part of the population[342]. In the end, a sample of 310 entities was obtained, contacted, and 151 questionnaires were returned – a return rate (response rate) of 48.7%. All questionnaires were filled in and were therefore accepted for analysis.

Due to the disproportionate selection of the sample concerning the population of enterprises from selected subclasses of PKD in the automotive industry, presented in Table 3.5, to reflect the structure of the population in Poland in the investigated enterprise size groups, post-stratification weighting[343] was applied, which increased the representativeness of the sample[344] and gave the possibility to generalise the results to the entire population of these entities.

Table 3.5. Structure of the population and sample of enterprises by employment size

Specification	Number of enterprises		Proportion of enterprises	
	Poland (2021)	Sample (2021)	Poland (2021)	Sample (2021)
Small (10–49 employees)	365	104	50.1	68.9
Medium (50–249 employees)	221	37	30.7	24.5
Large (more than 249 employees)	134	10	19.2	6.6
Total	720	151	100.0	100.0

Source: own elaboration based on Główny Urząd Statystyczny, *Kwartalna informacja…*

In addition, to test the similarity of the sample structure to the population for the key variables (a random sample test was conducted, which is used, among other things, to check whether the results of an experiment meet the random sample postulate. The series test (the Stevens series test or the Wald-Wolfowitz series test) was used for this purpose.

342 M. Baran, *Struktura procesu…*, p. 40.

343 The post-stratification weighting aimed to align the sample structure with that of the population from an employment size perspective. These weights applied ex-post also considered the unequal responsiveness within the sample. Thanks to the applied post-stratification weights, generalisations to the population of small, medium and large enterprises in the automotive industry in the selected PKD will be carried out with a risk of error of the first kind of no more than 5%. Broader: T. Jerzyński, *Poziom realizacji próby i ważenie poststratyfikacyjne w analizie danych sondażowych*, “Problemy Zarządzania” 2009, vol. 7(4), pp. 196–208.

344 A. Zakrzewska-Bielawska, S. Flaszewska, *Hybrydowa struktura organizacyjna z perspektywy paradoksu eksploracji i eksploatacji*, “Studia i Prace. Kolegium Zarządzania i Finansów” 2022, no. 183, p. 103.

Starting the analysis, the null hypothesis and the alternative hypothesis were formulated:

H0: the selection of entities into the sample is random,

H1: the selection of entities into the sample is not random.

The results of the sample randomness test for the key variables used to measure: the degree of knowledge and scope of application of Industry 4.0 requirements, technological potential, level of technological advantage, and level of competitive advantage confirmed the randomness of the sample – with an assumed significance level of $p < 0.05$.

The appropriate research was conducted on a sample of $n = 151$ automotive production enterprises functionating in Poland, comprising 104 small enterprises with 10 to 49 employees (68.9%), 37 medium enterprises with 50 to 249 employees (24.5%) and 10 large enterprises with more than 250 employees (6.6%).

Taking into account the age of the enterprise in years, it should be noted that enterprises functioning in the market for more than 15 years had the most significant representation in the sample – 45%, followed by those with 10 to 15 years – 32.4%. On the other hand, enterprises with up to 5 years and 5 to 10 years on the market had the smallest share, with 11.3% each (see Figure 3.3). In the case of small enterprises, enterprises with 10 to 15 years on the market had the highest share, followed by medium and large enterprises with more than 15 years on the market.

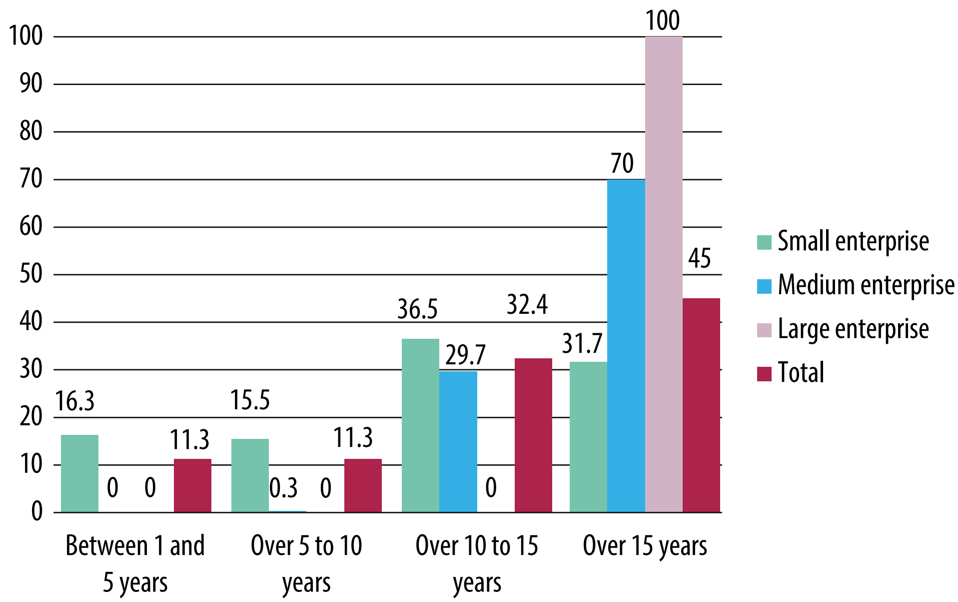

Figure 3.3. Structure of the surveyed sample by age of the enterprise (%)

Source: own elaboration.

Analysis of the structure of the surveyed enterprises by selected PKD subclasses showed that the most significant number of enterprises in the sample belonged to the Manufacture of other parts and accessories for motor vehicles excluding motorcycles 17.9% subclass and Manufacture of electrical and electronic equipment for motor vehicles and Manufacture of bearings, gears, gearing and driving elements subclass, with shares of 15.9% each. The least numerous subclasses in the sample were Manufacture of military fighting vehicles and Manufacture of motorcycles with shares of one enterprise each and Manufacture of cars, Manufacture of buses and Manufacture of batteries and accumulators with shares of two enterprises each (see Table 3.6).

Table 3.6. Structure of the surveyed sample by PKD subclasses (%)

Manufacture of other parts and accessories for motor vehicles excluding motorcycles (29.32.Z)	**17.9**
Manufacture of electrical and electronic equipment for motor vehicles (29.31.Z)	**15.9**
Manufacture of bearings, gears, gearing and driving elements (28.15.Z)	**15.9**
Manufacture of rubber tyres and tubes; retreading and rebuilding of rubber tyres (22.11.Z)	13.9
Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers (29.20.Z)	12.6
Manufacture of electric motors, generators and transformers (27.11.Z)	11.9
Manufacture of other motor vehicles excluding motorcycles (29.10.E)	2.6
Manufacture of engines for motor vehicles (excluding motorcycles) and for agricultural tractors (29.10.A)	2
Manufacture of motor vehicles for the transport of goods (29.10.D)	2
Manufacture of cars (29.10.B)	**1.3**
Manufacture of buses (29.10.C)	**1.3**
Manufacture of batteries and accumulators (27.20.Z)	**1.3**
Manufacture of military fighting vehicles (30.40.Z)	**0.7**
Manufacture of motorcycles (30.91.Z)	**0.7**

Source: own elaboration.

Considering the dominant market area of the enterprise, almost 63% of the surveyed entities functionated on the national market, 30.4% on the international and global market, and only 0.7% on the local market (see Figure 3.4). Small enterprises functionated mainly on the national market with 87.5%, medium enterprises on the international market with 73% and large enterprises on the global market with 80%.

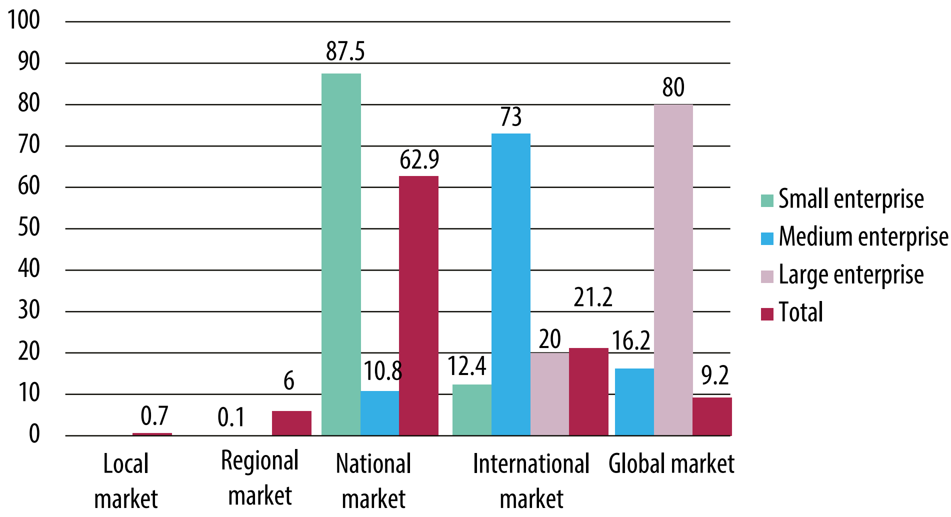

Figure 3.4. Structure of the surveyed sample by dominant market coverage of the enterprise in terms of turnover (%)

Source: own elaboration.

4. Building a technological advantage in the practice of SMART enterprises – research results

4.1. Quantitative research results – descriptive statistics

The first area of the conducted analysis of the empirical results was to assess the degree of familiarity with technologies resulting from the requirements of the age of Industry 4.0. 17 types of such technologies were included in the research[345]. The survey results showed that respondents were highly and very high familiar with Additive Manufacturing 31.1%, Robotisation 31.1%, and Geolocalisation 30.4%. In comparison, they were not or small familiar with Digital Twin 75.5%, Neural Networks 74.8%, Artificial Intelligence 74.2% and Virtual Reality, Augmented Reality 72.2% (see Table 4.1).

Surprisingly, small or no recognition is given to technologies dedicated primarily to production enterprises. They need to be combined with other state-of-the-art tools and equipment and do not occur individually but most often as a set of ready-to-use technological solutions to be implemented. The enterprises surveyed still need to be ready for such solutions.

Another area of research was to assess the degree of familiarity with the non-technological requirements of the age of Industry 4.0. 15 of these were included in the study[346]. The results of the research revealed that respondents were highly or very high familiar with the ability to work in a team 41.8%, desire for continuous development 41.7%, flexible and creative thinking 41.1%, ability to act quickly and make strategic decisions 40.4%, openness to new experiences 40.4%, ability to share knowledge 39%. Unfortunately, it was found that so far, the enterprises surveyed were not familiar or only small familiar with the open culture 68.9%, open business models 68.2%, decentralised decisions 67.6%, design thinking 67.6%, technical assistance 67%, open knowledge 66.9%, interconnection 66.9% and information transparency 66.9% (see Table 4.2). The results show that non-technological requirements directly related to the organisation of teamwork are the most well-known. However, knowledge of SMART management concepts, methods and tools useful in the age of Industry 4.0 could be more substantial. Therefore, managers still need to prepare for the challenges of the age

345 Rating on a scale of 1 to 5, where 1 – No familiarity, 2 – Small familiarity, 3 – Medium familiarity, 4 – High familiarity, 5 – Very high familiarity.

346 Rating on a scale of 1 to 5, where 1 – No familiarity, 2 – Small familiarity, 3 – Medium familiarity, 4 – High familiarity, 5 – Very high familiarity.

of Industry 4.0. The constant creation of new business needs and optimising current business areas makes this process difficult for them. Therefore, the current situation focuses mainly on the solutions necessary for proper communication, knowledge sharing and acquiring new skills dedicated to the rank-and-file in the age of Industry 4.0. There still needs to be more time and resources for more ambitious and unique solutions that are less widely practised.

Table 4.1. Degree of familiarity with technologies resulting from the requirements of the age of Industry 4.0 according to the enterprises surveyed (%)

Industry 4.0 technologies	Degree of familiarity				
	None (1)	Small (2)	Medium (3)	High (4)	Very high (5)
Internet of Things, Internet of Services	6.6	47.7	18.5	16.6	10.6
Cyber-Physical Systems	66.2	2.0	7.3	16.6	7.9
Information Network	62.3	6.0	2.0	14.6	15.1
Cloud Computing	7.3	51.7	11.3	17.9	11.8
Big Data Analytics	66.9	2.6	2.0	18.6	9.9
M2M Communication	67.5	0.7	4.0	18.5	9.3
Virtual Reality, Augmented Reality	**68.9**	**3.3**	9.9	11.3	6.6
Cybersecurity	0.7	49.7	21.2	13.2	15.2
Neural Networks	**68.2**	**6.6**	7.3	14.6	3.3
Digital Twin	**69.5**	**6.0**	6.6	11.9	6.0
Artificial Intelligence	**68.2**	**6.0**	9.9	11.9	4.0
Blockchain	67.5	1.3	6.6	15.3	9.3
Radio Frequency Identification	67.5	1.3	2.0	19.3	9.9
Geolocalisation	68.2	0.7	0.7	**13.2**	**17.2**
Additive Manufacturing	67.5	0.7	0.7	**17.9**	**13.2**
Robotisation	65.6	2.6	0.7	**19.2**	**11.9**
Mass Customisation	67.5	2.0	2.0	21.9	6.6

Source: own elaboration.

Table 4.2. Degree of familiarity with non-technological requirements of the age of Industry 4.0 according to the enterprises surveyed (%)

Non-technological requirements of Industry 4.0	Degree of familiarity				
	None (1)	Small (2)	Medium (3)	High (4)	Very high (5)
Open Resources	5.3	48.3	20.5	18.6	7.3
Open Knowledge	**65.6**	**1.3**	7.9	17.9	7.3
Open Culture	**66.9**	**2.0**	10.6	13.9	6.6
Interconnection	**66.9**	**0.0**	3.3	21.9	7.9
Decentralised Decisions	**66.9**	**0.7**	7.3	18.5	6.6

Non-technological requirements of Industry 4.0	Degree of familiarity				
	None (1)	Small (2)	Medium (3)	High (4)	Very high (5)
Information Transparency	**66.9**	**0.0**	4.6	20.6	7.9
Technical Assistance	**32.5**	**34.5**	2.0	15.8	15.2
Design Thinking	**66.9**	**0.7**	2.6	14.6	15.2
Open business models	**49.0**	**19.2**	6.6	17.3	7.9
Ability to act quickly and make strategic decisions	0.7	15.2	43.7	**26.5**	**13.9**
Ability to work in a team	0.0	15.2	43.0	**22.6**	**19.2**
Ability to share knowledge	0.0	14.6	46.4	**24.4**	**14.6**
Desire for continuous development	0.0	15.9	42.4	**27.8**	**13.9**
Flexible and creative thinking	0.0	15.9	43.0	**25.2**	**15.9**
Openness to new experiences	0.0	15.9	43.7	**25.2**	**15.2**

Source: own elaboration.

The next area of research was to assess the scope of application of technologies resulting from Industry 4.0 requirements[347]. Respondents applied Information Network 31.8%, Geolocalisation 26.5%, M2M Communication 24.5%, and Additive Manufacturing 24.5% to a large and very large scope. In contrast, they did not apply or have applied only to a small scope Neural Networks 94%, Artificial Intelligence 93.3%, Virtual Reality, Augmented Reality 92.7% and Digital Twin 91.4% (see Table 4.3). Interestingly, more is needed to apply technologies largely dedicated to SMART production enterprises as a bundle of associated technologies. These technologies are not commonly used by enterprises in the automotive industry functionating in Poland due to their high cost, limited availability, high complexity and time-consuming implementation. On the other hand, technologies applied to a large or very large scope are standard in the age of Industry 4.0, which makes it possible to build a suitable environment and adapt it for further development. The respondents are creating the base conditions in their enterprises to start competing more efficiently based on new technologies.

Table 4.3. Scope of application of technologies resulting from requirements of the age of Industry 4.0 according to the enterprises surveyed (%)

Industry 4.0 technologies	Scope of application				
	None (1)	Small (2)	Medium (3)	Large (4)	Very large (5)
Internet of Things, Internet of Services	14.6	59.6	20.5	4.0	1.3
Cyber-Physical Systems	68.2	6.6	7.9	12.7	4.6
Information Network	64.2	3.3	0.7	**11.9**	**19.9**

347 Rating on a scale of 1 to 5, where 1 – Did not apply, 2 – Applied to a small scope, 3 – Applied to a medium scope, 4 – Applied to a large scope, 5 – Applied to a very large scope.

Industry 4.0 technologies	Scope of application				
	None (1)	Small (2)	Medium (3)	Large (4)	Very large (5)
Cloud Computing	11.9	53.0	19.2	11.9	4.0
Big Data Analytics	68.2	3.3	12.6	11.9	4.0
M2M Communication	66.2	2.0	7.3	**14.6**	**9.9**
Virtual Reality, Augmented Reality	**83.4**	**9.3**	5.3	0.0	2.0
Cybersecurity	2.0	52.3	23.9	13.9	7.9
Neural Networks	**84.8**	**9.2**	4.0	2.0	0.0
Digital Twin	**82.1**	**9.3**	4.0	2.6	2.0
Artificial Intelligence	**83.4**	**9.9**	3.4	1.3	2.0
Blockchain	68.2	9.3	12.6	7.9	2.0
Radio Frequency Identification	68.9	2.0	5.3	19.8	4.0
Geolocalisation	68.2	1.3	4.0	**11.9**	**14.6**
Additive Manufacturing	68.9	2.6	4.0	**17.9**	**6.6**
Robotisation	66.9	7.3	7.9	11.9	6.0
Mass Customisation	68.2	2.6	13.9	7.4	7.9

Source: own elaboration.

The following research stage assessed the scope of which non-technological requirements of the age of Industry 4.0 were applied[348]. It was found that respondents applied the ability to work in a team 43.7%, flexible and creative thinking 43.7%, openness to new experiences 43.7%, desire for continuous development 42.4%, ability to share knowledge 40.4% to a high and very high scope, and no or small application of decentralised decisions 86.1%, open business models 82.8% and open culture 81.5% (see Table 4.4). Again, the results showed that non-technological solutions directly supporting the workforce competencies needed in a SMART environment are most commonly used. Solutions supporting managers to manage the entities developing according to the main requirements and principles of the age of Industry 4.0 are rare, and it is a significant barrier to the development of the researched enterprises. With a change in approach and appropriate development of knowledge, skills and attitudes among managers and employees, it is possible to effectively build a competitive advantage in the age of Industry 4.0[349].

348 Rating on a scale of 1 to 5, where 1 – Did not apply, 2 – Applied to a small scope, 3 – Applied to a medium scope, 4 – Applied to a large scope, 5 – Applied to a very large scope.

349 A. Adamik, M. Nowicki, *Barriers of Creating Competitive Advantage in the Age of Industry 4.0: conclusions from International Experience*, [in:] A. Zakrzewska-Bielawska, I. Staniec (eds.), *Contemporary challenges in Cooperation and Coopetition in the age of Industry 4.0*, Springer, Cham 2020, pp. 3–42.

Table 4.4. Scope of application of non-technological requirements of the age of Industry 4.0 according to the enterprises surveyed (%)

Non-technological requirements of Industry 4.0	Scope of application				
	None (1)	Small (2)	Medium (3)	Large (4)	Very large (5)
Open Resources	8.6	58.3	27.2	3.3	2.6
Open Knowledge	**66.2**	**7.3**	10.6	12.6	3.3
Open Culture	72.2	9.3	9.3	9.2	0.0
Interconnection	67.5	2.6	6.7	18.6	4.6
Decentralised Decisions	**74.2**	**11.9**	8.6	4.0	1.3
Information Transparency	66.9	2.6	7.9	17.9	4.7
Technical Assistance	31.8	35.1	5.3	14.6	13.2
Design Thinking	66.9	2.0	4.0	17.2	9.9
Open business models	**57.0**	**25.8**	9.2	6.0	2.0
Ability to act quickly and make strategic decisions	2.0	15.2	46.4	25.8	10.6
Ability to work in a team	0.0	15.9	40.4	**29.1**	**14.6**
Ability to share knowledge	0.0	15.2	44.4	**30.5**	**9.9**
Desire for continuous development	0.0	17.9	39.7	**28.5**	**13.9**
Flexible and creative thinking	0.0	17.2	39.1	**29.8**	**13.9**
Openness to new experiences	0.0	16.6	39.7	**31.8**	**11.9**

Source: own elaboration.

Another part of the research conducted was to assess the level of development of the enterprise's technological potential in six areas. The first of these was the technology portfolio[350]. Analysis of the level of development of the technological potential of the surveyed enterprises in the technological portfolio showed that the level is very low in 4% of the surveyed enterprises, low in 6%, and medium in 68.9%. In comparison, high and very high in 21.1% (see Figure 4.1). This shows that the enterprises surveyed already have a specific set of technologies at their disposal, which they can use efficiently. Therefore, they have a starting base, which constitutes an opportunity to develop their technological potential and advantage efficiently. However, they should still consciously work on this process because continuous development is required in the age of Industry 4.0, which determines the integration of many areas based on technological aspects. Only such an approach makes adapting to a dynamically changing environment in a SMART world possible.

350 Rating on a scale of 1 to 5, where 1 – Very Low, 2 – Low, 3 – Medium, 4 – High, 5 – Very high.

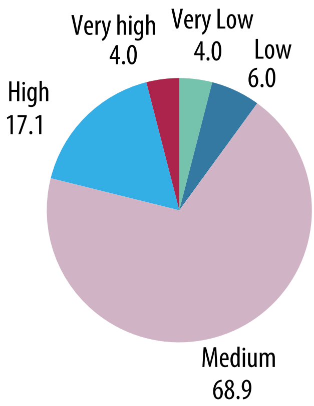

Figure 4.1. The level of development of the technological potential of the surveyed enterprises in the area of technological portfolio (%)
Source: own elaboration.

Next, the level of development of technological potential in the area of intangible assets, including know-how, was assessed[351]. The analysis showed that the level of development of the surveyed enterprises in this area is very low at 65.6%, low at 3.3%, and medium at 9.9%. In comparison, it is high or very high at 21.2% (see Figure 4.2). These results show that, among the enterprises researched, intangible assets still contribute relatively little to their technological potential. It indicates a dependence on partners from which these solutions are obtained, which is limited to their subsequent copying. Such actions may result in the need for sufficient experience, expertise in technology, production process and the absence of original unique solutions. The consequence of neglect in this area is a low level of technological advantage and the resulting competitive advantage.

The next step of the research assessed the level of development of technological potential in the area of R&D activities effectiveness[352]. The analysis showed that the level of development in this area is very low in 68.2% of the researched enterprises, low in 0.7%, and medium in 8.6%. In comparison, high and very high in 22.5% (see Figure 4.3). These results show that, among the enterprises surveyed, the effectiveness of R&D activities still has a relatively small impact on the level of development of their technological potential. The fact that a small percentage of the researched enterprises effectively conduct R&D activities results in a low level of innovation in the industry. It is probably due to the need for more allocation of resources for this type of activity,

351 Rating on a scale of 1 to 5, where 1 – Very Low, 2 – Low, 3 – Medium, 4 – High, 5 – Very high.
352 Rating on a scale of 1 to 5, where 1 – Very Low, 2 –Low, 3 – Medium, 4 – High, 5 – Very high.

too high dynamics of technological progress, and limited possibilities to access valuable external sources of financing among the researched[353].

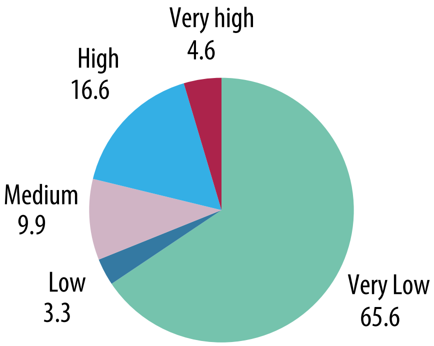

Figure 4.2. The level of development of the technological potential of the surveyed enterprises in the area of intangible assets, including know-how (%)

Source: own elaboration.

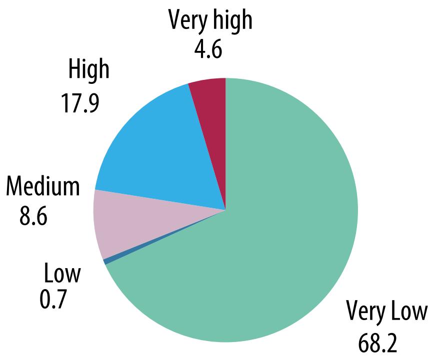

Figure 4.3. The level of development of the technological potential of the surveyed enterprises in the area of R&D activities effectiveness (%)

Source: own elaboration.

A further stage of the research assessed the level of development of technological potential in the area of technological entrepreneurship[354]. The analysis showed that the technological potential development level in technological entrepreneurship is very low in 10.6% of the surveyed enterprises, low in 31.8%, and medium in 35.1%. In comparison, high and very high in 22.5% (see Figure 4.4). The results show that technological entrepreneurship already has a reasonably significant impact on the level of development

353 M. Piekut, *Działalność B+R czynnikiem rozwoju przedsiębiorstw*, "Kwartalnik Nauk o Przedsiębiorstwie" 2011, vol. 20(3), pp. 87–95.

354 Rating on a scale of 1 to 5, where 1 – Very Low, 2 – Low, 3 – Medium, 4 – High, 5 – Very high.

of the technological potential of the respondents. It means that the development of new technologies today already has a considerable impact on the creation of new products, flexible response to market changes and the development of the technological potential of SMART enterprises. Enterprises are becoming increasingly active in taking market risks, quality of operations, taking up challenges, increasing the effectiveness of R&D activities, and raising the level of creativity and technological competence of management[355]. Although this is yet to be an exemplary level of commitment, it is an important starting point for the rapid intensification of activities and achievements.

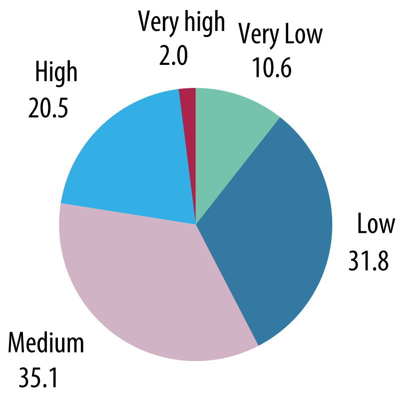

Figure 4.4. The level of development of the technological potential of the surveyed enterprises in the area of technological enterpreneurship (%)

Source: own elaboration.

The next step of the research process assessed the level of development of the technological potential of the surveyed enterprises in the area of the intellectual potential of their employees[356]. Analysis of the level of development of technological potential in the area of intellectual potential of employees showed that the level of development is very low in 2.6% of the surveyed enterprises, low in 0.7%, and medium in 3.3%. In comparison, high and very high in 93.4% (see Figure 4.5). The results show that the intellectual development of employees is a significant area of technological potential, given its high level in the majority of respondents. Considering the previous results, a robust emphasis is placed on employee development in the Polish automotive industry. Their knowledge and competencies are the selected SMART enterprises' critical success factors.

355 Z. Chyba, *Przedsiębiorczość technologiczna*…, pp. 63–67.

356 Rating on a scale of 1 to 5, where 1 – Very Low, 2 – Low, 3 – Medium, 4 – High, 5 – Very high.

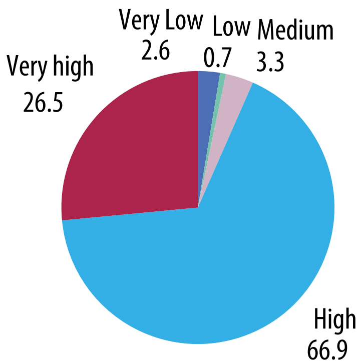

Figure 4.5. The level of development of the technological potential of the surveyed enterprises in the area of intellectual potential of employees (%)
Source: own elaboration.

The last area researched in this part of the analysis was the assessment of the competitiveness of available technologies[357]. This analysis showed that the level is very low in 5.3% of the enterprises researched, low in 26.5%, and medium in 39.7%, while high and very high in 28.5% (see Figure 4.6). The results show that technology competitiveness is, on average, an important area of technological potential. In the enterprises researched, technologies that result from their R&D activities need to be created at a higher level to influence the development of their overall technological potential. Technologies gathered from external sources need to be emerging. Hence the comprehensive evaluation of potential still leaves much to be desired. A stronger focus of the researchers on a more conscious selection and exploitation of better and better technologies of both own and external production is necessary. Another aspect is the low level of competitiveness of the basic and core technologies, which were used most frequently by the enterprises surveyed.

Another part of the research undertaken in the scientific monograph concerned the assessment of the intensity of the application of basic technologies (described in more detail in chapter 2) by the enterprises surveyed in the last three years (2019–2021)[358]. The analysis of the intensity of application of basic technologies showed that these technologies were not applied by 15.9% of the enterprises surveyed, to a low and medium intensity of 53.6%. In comparison, 30.5% application of these technologies to a large and very large intensity (see Figure 4.7). The results, therefore, show that the vast majority of the enterprises surveyed use basic technologies that are commercially available and enable their operation. This technology is the starting point for developing

357 Rating on a scale of 1 to 5, where 1 – Very Low, 2 – Low, 3 – Medium, 4 – High, 5 – Very high.
358 Rating on a scale of 1 to 5, where 1 – None, 2 – Low intensity, 3 – Medium intensity, 4 – High intensity, 5 – Very high intensity.

and implementing new solutions in the age of Industry 4.0 and building SMART enterprises' technological advantage. More than having this group of technologies is needed to think realistically about market success in a SMART world environment.

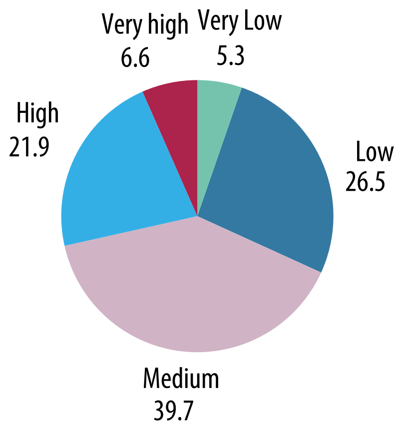

Figure 4.6. The level of development of the technological potential of the surveyed enterprises in the area of competitiveness of available technologies (%)

Source: own elaboration.

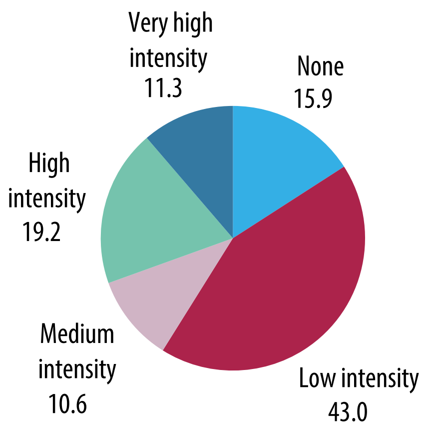

Figure 4.7. The intensity of application of basic technologies in surveyed enterprises in 2019–2021 (%)

Source: own elaboration.

The next step of the analysis assessed the intensity of application of slightly more advanced technologies, i.e. core technologies (described in more detail in chapter 2), by the enterprises surveyed in the last three years (2019–2021)[359]. The analysis of the intensity of application of core technologies showed that these technologies were not applied at all by 60.3% of the researched enterprises, to a low and medium intensity by 15.9%. In comparison, 23.8% application of these technologies to a large and very large intensity (see Figure 4.8). Thus, the data collected shows that far fewer enterprises surveyed use core technologies than basic technologies. They are more individual and thus form a unique set of competitive technologies. They require more significant investment and competence to create and implement them in the age of Industry 4.0, thus confirming the higher level of the SMART enterprises researched in terms of technological sophistication.

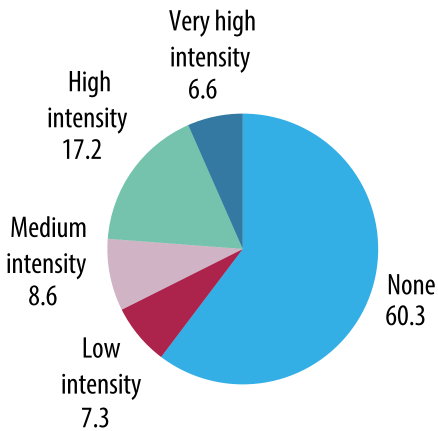

Figure 4.8. The intensity of application of core technologies in surveyed enterprises in 2019–2021 (%)

Source: own elaboration.

It was followed by an assessment of the intensity of the application of emerging technologies (described in more detail in chapter 2) by the enterprises surveyed in the last three years (2019–2021)[360]. An analysis of the intensity of application of emerging technologies showed that these technologies were not applied at all by 66.9% of the enterprises surveyed, to a low and medium intensity of 14.5%. In comparison, 18.6% applied these technologies to a large and very large intensity (see Figure 4.9). Surprisingly, the intensity of application of emerging technologies among the enterprises surveyed differed little from that of core technologies. The two types of technologies are somewhat dependent. Both are individual, forming together a set of competitive technologies

359 Rating on a scale of 1 to 5, where 1 – None, 2 – Low intensity, 3 – Medium intensity, 4 – High intensity, 5 – Very high intensity.

360 Rating on a scale of 1 to 5, where 1 – None, 2 – Low intensity, 3 – Medium intensity, 4 – High intensity, 5 – Very high intensity.

of the SMART enterprise. Emerging technologies are innovative and pioneering in their field, most often resulting from effective R&D activities, and their presence confirms the highest degree of technological sophistication of the enterprises exploiting them.

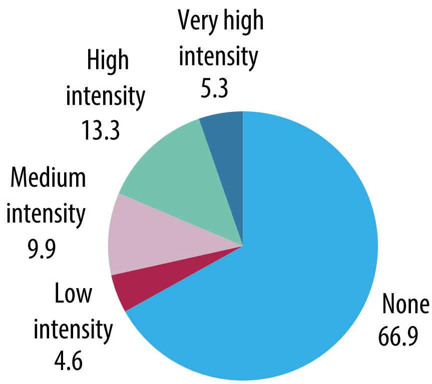

Figure 4.9. The intensity of application of emerging technologies in surveyed enterprises in 2019–2021 (%)

Source: own elaboration.

Another part of the research conducted was to assess the intensity of the occurrence of the various forms of R&D activity of the enterprises surveyed in the last three years (2019–2021). The first of these was the conduct of R&D activity itself[361]. The analysis showed that 67.5% of the researched enterprises had no R&D activity, and 15.8% indicated a high and very high intensity of the occurrence of this form of R&D activity (see Figure 4.10). The implication is that the majority of the enterprises surveyed do not carry out R&D activities. The main reason may be the high costs of conducting this type of activity due to the high speed of technology obsolescence and the unpredictability of the results obtained. Unfortunately, enterprises in the age of Industry 4.0 and SMART world environment that do not conduct R&D activities have no chance of improving their market position and, consequently, their competitiveness[362]. Therefore, the results could be more optimistic about the situation of the analysed SMART enterprises of the automotive industry.

The second observed form of R&D activity was the development by the researched enterprises of infrastructure for this type of activity[363]. The analysis showed that

361 Rating on a scale of 1 to 5, where 1 – None, 2 – Low intensity, 3 – Medium intensity, 4 – High intensity, 5 – Very high intensity.

362 ASM – Centrum Badań i Analiz Rynku Sp. z o.o., *Raport końcowy – Ocena zapotrzebowania przedsiębiorstw na wsparcie działności badawczo-rozwojowej*, Warszawa 2013.

363 Rating on a scale of 1 to 5, where 1 – None, 2 – Low intensity, 3 – Medium intensity, 4 – High intensity, 5 – Very high intensity.

68.2% of the surveyed enterprises did not develop R&D infrastructure, and 16.1% indicated a high and very high intensity of occurrence of this form of R&D activity (see Figure 4.11). Most of the enterprises surveyed need to be developing R&D infrastructure. The main reason may be the high costs of conducting this activity, and the small percentage of enterprises conducting R&D. Enterprises need to develop R&D infrastructure because they do not have it and cannot afford to initiate it. Infrastructure development requires high expenditures due to the sophistication of tools, equipment and processes that allow for effective R&D activities.

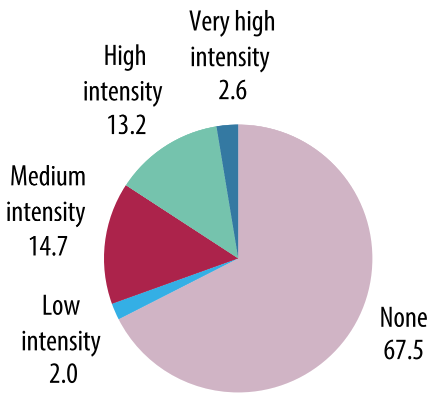

Figure 4.10. The intensity of conducting R&D activities in surveyed enterprises in 2019–2021 (%)

Source: own elaboration.

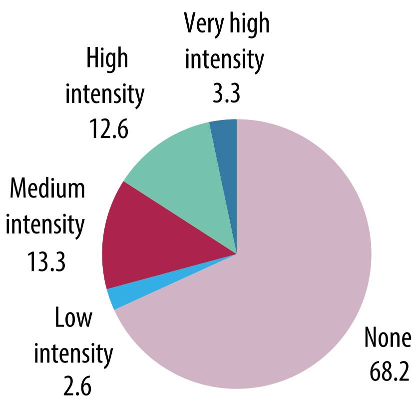

Figure 4.11. The intensity of development of R&D infrastructure in surveyed enterprises in 2019–2021 (%)

Source: own elaboration.

The third form of R&D activity analysed was investment in this type of activity[364]. The analysis showed that 68.2% of the researched enterprises did not invest in R&D activity, and 19.9% indicated a high and very high intensity of occurrence of this form of R&D activity (see Figure 4.12). The implication is that most enterprises surveyed do not invest in R&D activities. The main reason for this may be the very high costs of conducting this type of activity, and enterprises want to avoid incurring considerable expenses for not entirely sure effects of this activity. There is a very high risk of failure, which may result in significant losses. Unfortunately, reducing R&D spending reduces turnover and enterprise market competitiveness[365]. Again, the respondents have somewhat limited possibilities to develop their technological potential.

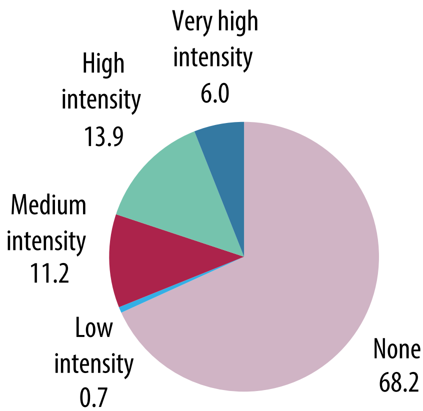

Figure 4.12. The intensity of investment in R&D activity in surveyed enterprises in 2019–2021 (%)
Source: own elaboration.

Another form of R&D activity researched was the development of its employees[366]. The analysis showed that 68.2% of the surveyed enterprises did not develop their R&D employees, and 27.8% indicated a high and very high intensity of occurrence of this form of R&D activity (see Figure 4.13). The implication is that most enterprises surveyed need to develop their R&D staff sufficiently. The main reason is the generally low proportion of enterprises with R&D activities. Enterprises do not develop their R&D staff because they do not carry out this type of activity and do not want to invest in increasing the competencies of their employees without the possibility of using them effectively later on to benefit their profits. A common practice is to source off-the-shelf

364 Rating on a scale of 1 to 5, where 1 – None, 2 – Low intensity, 3 – Medium intensity, 4 – High intensity, 5 – Very high intensity.

365 P.N. SubbaNarasimha, S. Ahmad, S.N. Mallya, *Technological Knowledge*…

366 Rating on a scale of 1 to 5, where 1 – None, 2 – Low intensity, 3 – Medium intensity, 4 – High intensity, 5 – Very high intensity.

solutions from other enterprises in the market, allowing the use of proven solutions that reduce the risk of losses. With this approach, enterprises are at least attempting to build their competitiveness in the age of Industry 4.0 in this limited way.

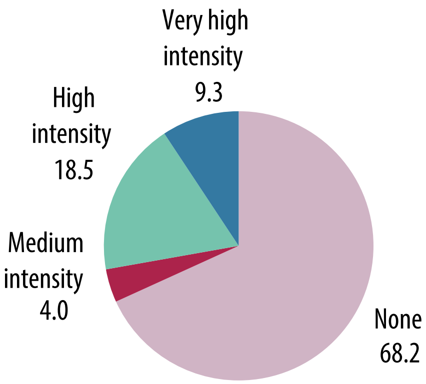

Figure 4.13. The intensity of development of R&D employees in surveyed enterprises in 2019–2021 (%)

Source: own elaboration.

The final form of R&D activity analysed during the research process was the cooperation with external R&D centres, e.g. universities[367]. The analysis showed that 62.9% of the surveyed enterprises did not cooperate with external R&D centres, and 25.2% indicated a high and very high intensity of occurrence of this form of R&D activity (see Figure 4.14). The reason for such a poor result may be informal factors, which often refer to significant differences between science and business. From the point of view of enterprises starting R&D activities, cooperation with the scientific sphere is relatively simple due to their limited financial possibilities[368]. On the other hand, enterprises with R&D activities collaborate very intensively with external R&D centres, as it is sometimes uneconomic to achieve the goals alone and requires close cooperation to achieve greater competitiveness in the market[369].

Another area of analysis undertaken during the research process was assessing the level of competitive advantage of the surveyed enterprises concerning 10 selected competitiveness factors[370]. Respondents rated high and very high the competence of employees at 99.3%, price of products/services at 94.7%, quality of products/services

367 Rating on a scale of 1 to 5, where 1 – None, 2 – Low intensity, 3 – Medium intensity, 4 – High intensity, 5 – Very high intensity.

368 ASM – Centrum Badań i Analiz Rynku Sp. z o.o., *Raport końcowy…*

369 W. Mierzejewska, A. Sopocińska, *Modele współpracy w zakresie prac badawczo-rozwojowych w grupach kapitałowych*, "Organizacja i Kierowanie" 2017, no. 2, pp. 357–369.

370 Rating on a scale of 1 to 5, where 1 – Very low, 2 – Low, 3 – Medium, 4 – High, 5 – Very high.

at 94.7%, financial capabilities at 93.3%, and lowest the knowledge and technological know-how at 66.9% and technological innovations at 39.7% (see Table 4.5). Unsurprisingly, factors directly related to technology are rated the lowest, given that technology is critical in the age of Industry 4.0. It is directly related to previous results, which showed that the enterprises surveyed do not perform effective R&D, significantly limiting technological innovation. Lack of sufficient experience and expertise in technology and production process translates into deficiencies in technological know-how. However, in relation to competitiveness factors such as competence of employees, financial capabilities, price and quality of products/services, the researched enterprises rated the level of perceived competitive advantage as high. It shows that the technological sphere significantly deviates from the business and quality spheres regarding the level of competitive advantage. It may be directly related to the limited access to the latest technological solutions used in production processes enabling the construction of competitive advantage based on these technology-related competitive factors.

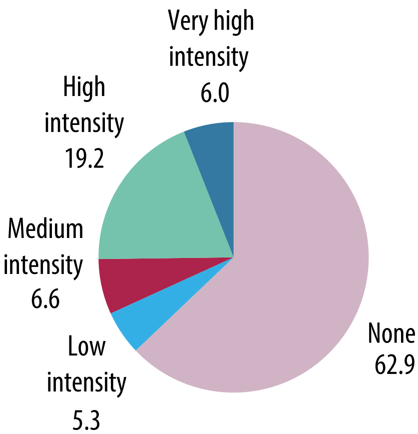

Figure 4.14. The intensity of cooperation with external R&D centres in surveyed enterprises in 2019–2021 (%)

Source: own elaboration.

Table 4.5. Assessment of the impact of selected competitiveness factors on the level of competitive advantage perceived by the surveyed enterprises (%)

Competitiveness factors	Level of competitive advantage				
	Very low (1)	Low (2)	Medium (3)	High (4)	Very high (5)
Competence of employees	0.0	0.0	0.7	**68.8**	**30.5**
Knowledge and technological know-how	**61.6**	**5.3**	2.0	17.9	13.2
Technological innovations	**6.6**	**33.1**	13.9	35.1	11.3

Competitiveness factors	Level of competitive advantage				
	Very low (1)	Low (2)	Medium (3)	High (4)	Very high (5)
Capacity for inter-organisational cooperation	4.6	9.3	15.9	58.9	11.3
Customer relations	0.0	0.0	11.9	75.5	12.6
Attractive and differentiated offer	0.0	2.0	9.9	78.2	9.9
Corporate image	0.0	1.3	9.9	79.5	9.3
Financial capabilities	0.0	0.7	6.0	**76.1**	**17.2**
Price of products/services	0.0	0.7	4.6	**74.8**	**19.9**
Quality of products/services	0.0	0.7	4.6	**78.8**	**15.9**

Source: own elaboration.

In the next step of the analysis, the respondents assessed the current competitive position of the enterprise under research, taking into account the four meters of the competitive position indicated[371]. The current competitive position was mainly considered medium in all the cases researched. Respondents rated high and very high share in sales at 17.9%, the lowest return on investment at 18.5%, and sales dynamics at 20.5% (see Figure 4.15). The results show that the researched enterprises take a rather assertive approach to assessing their current competitive position, and they cannot state what generates it and how strongly. It also shows that the researched enterprises cannot fully determine their readiness for the age of Industry 4.0[372]. The results of research into other issues studied corroborate this.

The next part of the research examined how the meters of an enterprise's competitive position have changed over the past three years (2019–2021)[373]. The analysis of the change in the meters of the competitive position of the enterprises researched between 2019 and 2021 showed that 70.1% of the entities increased their share of sales, including about 9.8%, by more than 10%. In the case of the change in sales dynamics between 2019 and 2021, almost 57% of enterprises recorded an increase in sales dynamics, including 2.7% by more than 10%. In turn, the profitability analysis showed that 56.9% of the enterprises researched saw an increase in profitability, including 3.3% by more than 10%. In the case of return on investment, 60% of the entities showed an increase in this rate, including 1.3% by more than 10%, indicating that the investments undertaken by these enterprises were profitable (see Figure 4.16). It shows that the production enterprises researched strive to meet the customer requirements of the age

371 Rating on a scale of 1 to 5, where 1 – Very low, 2 – Low, 3 – Medium, 4 – High, 5 – Very high.

372 A. Adamik, M. Nowicki, *Preparedness of companies for digital transformation and creating a competitive advantage in the age of Industry 4.0*, "Proceedings of the International Conference on Business Excellence" 2018, vol. 12(1), pp. 10–24.

373 Respondents entered the appropriate value in %, signalling a growth or decrease.

of Industry 4.0, which increases sales and sales dynamics. The conscious application of Industry 4.0 requirements makes it possible to raise customer satisfaction, resulting in loyalty and brand loyalty. The findings also show that enterprises' investments have been profitable, which can be directly linked to technological development, which makes it possible to increase productivity and production efficiency, resulting in a broader product range while reducing operating costs.

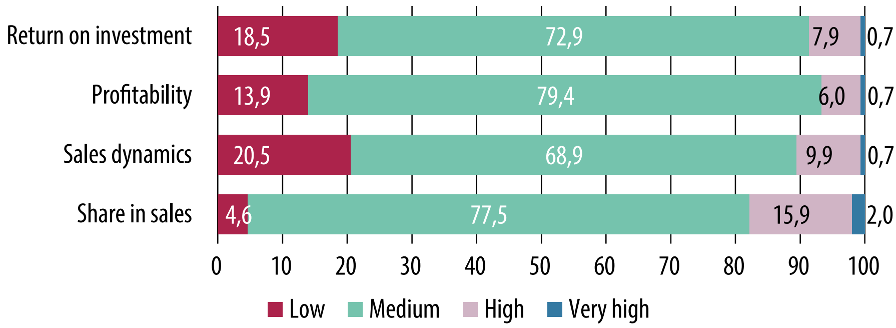

Figure 4.15. Assessment of the current competitive position in the surveyed enterprises (%)

Source: own elaboration.

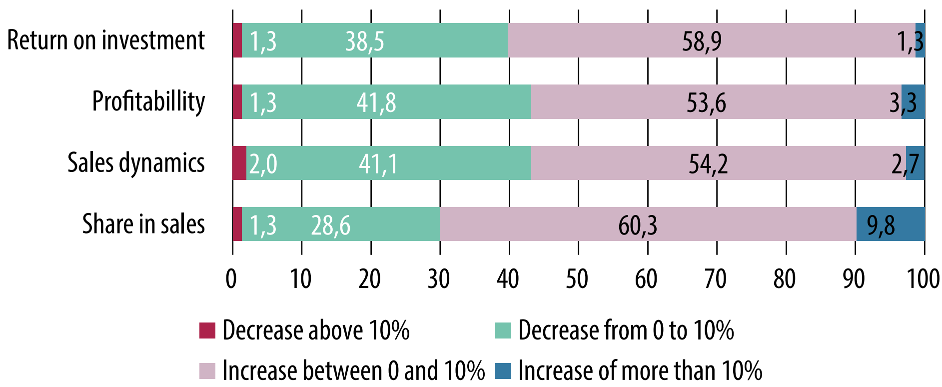

Figure 4.16. Changes in meters of competitive position in the surveyed enterprises in 2019–2021 (%)

Source: own elaboration.

Summarising this part of the results, the researched automotive production enterprises functionating in Poland do not have sufficient knowledge of the technologies necessary for an effective and efficient production process in the age of Industry 4.0. Most of the researched enterprises use only basic technologies necessary only for basic operations. On the other hand, more advanced core technologies or pioneering emerging technologies are applied with low intensity, which only allows one to take full advantage of technological opportunities to compete in the market and build a clear competitive advantage based on technological advantage. The enterprises researched need sufficient knowledge of the technological and non-technological requirements of the age of Industry 4.0. Moreover, they must improve their human and relational potential in this area. It makes it significantly more difficult to compete internationally due to their lower level of development than their foreign competitors.

The above results confirm the relevance of the selection and timeliness of the topic undertaken in the scientific monograph. In this situation, it seems very important not only to show the importance of new technologies in SMART enterprises operating in the age of Industry 4.0 or to indicate those solutions that have a key impact on building a technological advantage today but also to recommendations to support processes of their more effective use. Therefore, analysing the results so far, an attempt will be made (subchapter 4.4) to create a procedure to follow in the process of building a technological advantage in the Industry 4.0 environment. This procedure will provide support in terms of estimating the current level of technological advantage of a given enterprise and hints as to the direction of its further development. It will also indicate what conditions should be met for the technology used to increase the level of competitive advantage of SMART enterprises effectively.

4.2. Quantitative research results – correlation analysis

This part of the study aims to identify and verify the relationship between the analysed variables describing Industry 4.0 requirements, technological potential, level of technological advantage, current competitive position and level of competitive advantage and selected enterprise characteristics.

The first stage of the analysis attempted to answer whether there is a relationship between the degree of familiarity with Industry 4.0 technologies and the age and size of the enterprise. To this end, a SIDFI4.0T was calculated for each enterprise researched, the sum of the respondents' assessment scores for the 17 types of technologies[374]. This indicator can range from 17 to 85[375], and the higher the level, the better the degree of familiarity of the surveyed enterprise with Industry 4.0 technologies.

Next, the researched enterprises' degree of familiarity with Industry 4.0 technologies was assessed considering their age. To assess this relationship, the non-parametric

374 For a detailed analysis of the types of Industry 4.0 technologies, see subchapter 4.1.

375 Due to the design of the questionnaire, respondents' answers were assigned points ranging from 1–5, which in this case gives a minimum value of 17 and a maximum value of 85.

Kruskal-Wallis[376] test was used, as the assumptions for the use of one-way analysis of variance (ANOVA – Analysis Of Variance)[377]were not met, i.e. the distribution of variables in each population deviated from a normal distribution (this was confirmed by the results of the Shapiro-Wilk test[378]) and there was no homogeneity of variance in all subpopulations (groups). The results of the Kruskal-Wallis test (statistic value H = 22.440, $p < 0.001$) confirmed the existence of statistically significant differences between the analysed variables, i.e. the degree of familiarity with Industry 4.0 technologies and the age of the enterprise. To check between which enterprises these differences could be observed, a mean rank analysis of the degree of familiarity with Industry 4.0 technologies was performed (see Table 4.6), which showed that statistically significant differences should be expected between the youngest enterprises (1 to 5 years on the market) and the oldest enterprises (more than 15 years on the market).

Table 4.6. Mean ranks of the degree of familiarity with Industry 4.0 technologies of the researched enterprises by their age

Age of enterprise	N	Mean rank
Between 1 and 5 years	17	46.0
Over 5 years to 10 years	17	66.2
Over 10 years to 15 years	49	66.4
Over 15 years	68	92.9
Total	151	

Source: own elaboration.

To test whether the remaining differences are significant, a pairwise multiple comparison analysis of the degree of familiarity with Industry 4.0 technologies relative to the age of the enterprise was performed (see Table 4.7).

The analysis shows that the degree of familiarity with Industry 4.0 technologies is significantly higher in the oldest enterprises (over 15 years on the market) than the degree of familiarity with these technologies in the youngest enterprises (between 1 and 5 years on the market) and enterprises over 10 years to 15 years on the market. In other cases, there are no grounds to reject the null hypothesis, as the differences between the analysed variables are not statistically significant (see Figure 4.17).

376 Broader described in chapter 3.

377 Broader described in chapter 3.

378 Broader described in chapter 3.

Table 4.7. Pairwise multiple comparison of the degree of familiarity with Industry 4.0 technologies of the researched enterprises by their age

Sample 1 – Sample 2	Test statistics	Standard error y	Standardised test statistic	Significance	Adjusted significance[a]
Between 1 and 5 years – over 5 years to 10 years	– 20.206	14.615	– 1.383	0.167	1.000
Between 1 and 5 years – over 10 years to 15 years	– 20.418	11.994	– 1.702	0.089	0.532
Between 1 and 5 years – over 15 years	– 46.853	11.554	– 4.055	< 0.001	0.000*
Over 5 years to 10 years – over 10 years to 15 years	– 0.212	11.994	– 0.018	0.986	1.000
Over 5 years to 10 years – over 15 years	– 26.647	11.554	– 2.306	0.021	0.127
Over 10 years to 15 years – over 15 years	– 26.435	7.985	– 3.311	< 0.001	0.006*

Each row tests the null hypothesis that the distributions of Sample 1 and Sample 2 are the same.
Asymptotic significance is displayed (2-sided tests). The significance level is 0.05.
[a] Significance values were adjusted using the Bonferroni method.
* Statistically significant relationship.

Source: own elaboration.

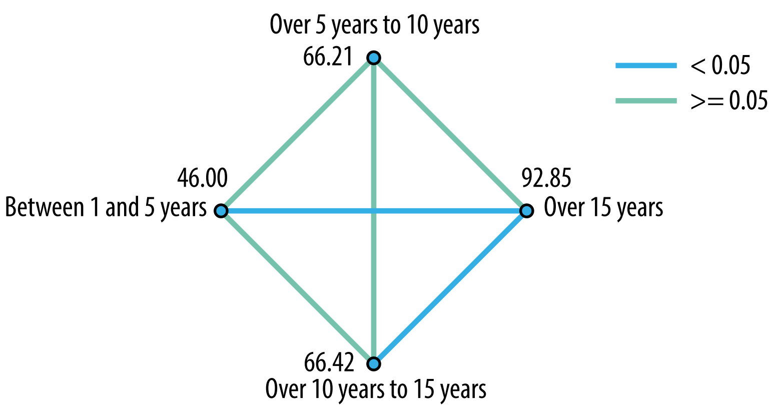

Figure 4.17. Pairwise multiple comparison of the degree of familiarity with Industry 4.0 technologies of the enterprises researched by their age

Source: own elaboration.

In the next stage of the analysis, the degree of familiarity with Industry 4.0 technologies by the researched enterprises was assessed considering the criterion of their size. The non-parametric Kruskal-Wallis test was also used to determine this relationship, as the assumptions for the use of a one-factor analysis of variance were not met. The results of this test (statistic value H = 102.22, $p < 0.001$) confirmed the existence of statistically significant differences between the analysed variables, i.e. the degree of familiarity with Industry 4.0 technologies and the size of the enterprise. To assess which enterprises these differences could be observed, a mean rank analysis of the degree of familiarity with Industry 4.0 technologies was performed (see Table 4.8), showing that statistically significant differences should be expected between small and large enterprises.

Table 4.8. Mean ranks of the degree of familiarity with Industry 4.0 technologies of the researched enterprises by their size

Enterprise size	N	Mean rank
Small enterprise	104	52.70
Medium enterprise	37	122.68
Large enterprise	10	145.65
Total	151	

Source: ownelaboration.

To test whether the remaining differences are significant, a pairwise multiple comparison analysis of the degree of familiarity with Industry 4.0 technologies relative to the size of the enterprise was performed (see Table 4.9).

Table 4.9. Pairwise multiple comparison of the degree of familiarity with Industry 4.0 technologies of the researched enterprises by their size

Sample 1 – Sample 2	Test statistics	Standard error y	Standardised test statistic	Significance	Adjusted significance[a]
Small enterprise – Medium enterprise	– 69.979	8.157	– 8.579	0.000	0.000*
Small enterprise – Large enterprise	– 92.953	14.107	– 6.589	<0.001	0.000*
Medium enterprise – Large enterprise	– 22.974	15.187	– 1.513	0.130	0.391

Each row tests the null hypothesis that the distributions of Sample 1 and Sample 2 are the same.
Asymptotic significance is displayed (2-sided tests). The significance level is 0.05.
[a] Significance values were adjusted using the Bonferroni method.
* Statistically significant relationship.

Source: own elaboration.

As previously expected, the degree of familiarity with Industry 4.0 technologies is significantly lower in small enterprises than in large enterprises. Small enterprises showed weaker familiarity with Industry 4.0 technologies compared to medium enterprises. In contrast, the difference in the degree of familiarity with Industry 4.0

technologies in medium and large enterprises is not statistically significant, as shown in Figure 4.18.

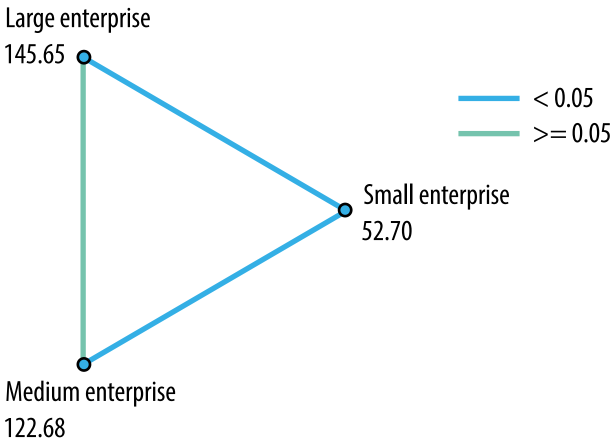

Figure 4.18. Pairwise multiple comparison of the degree of familiarity with Industry 4.0 technologies of the enterprises researched by their size

Source: own elaboration.

Continuing with the analysis of the relationship between the variables, an attempt was made to answer whether there was a relationship between the degree of familiarity with the non-technological requirements of Industry 4.0 and the age and size of the enterprise. By analogy with the first part of this subsection, the SIDFNTRI4.0 was calculated for each enterprise researched, a sum of the respondents' assessment scores of 15 of these requirements[379]. The value of this indicator ranges from 15 to 75[380], and the higher its level, the better the degree of familiarity of the researched enterprise with the non-technological requirements of Industry 4.0.

The degree of familiarity with the non-technological requirements of Industry 4.0 by the enterprises surveyed was then assessed concerning age. The non-parametric Kruskal-Wallis test[381] was also used to determine this relationship, as the assumptions for using one-way analysis of variance (ANOVA – Analysis Of Variance) were also not met. The results of the Kruskal-Wallis test (statistic value H = 41.728, $p < 0.001$) confirmed the existence of statistically significant differences between the analysed variables, i.e. the degree of familiarity with the non-technological requirements of Industry 4.0 and the age

379 For a detailed analysis of the dimensions describing the non-technological requirements of Industry 4.0, see subchapter 4.1.

380 Due to the design of the questionnaire, respondents' answers were assigned points ranging from 1–5, which in this case gives a minimum value of 15 and a maximum value of 75.

381 Broader described in chapter 3.

of the enterprise. To check between which enterprises these differences could be observed, a mean rank analysis of the degree of familiarity with the non-technological requirements of Industry 4.0 was performed (see Table 4.10), which showed that statistically significant differences should be expected between the youngest enterprises (1 to 5 years on the market) and the oldest enterprises (more than 15 years on the market).

Table 4.10. Mean ranks of the degree of familiarity with non-technological Industry 4.0 requirements of the researched enterprises by their age

Age of enterprise	N	Mean rank
Between 1 and 5 years	17	36.03
Over 5 years to 10 years	17	41.82
Over 10 years to 15 years	49	71.95
Over 15 years	68	97.46
Total	151	

Source: own elaboration.

To test whether the remaining differences are significant, a pairwise multiple comparison analysis of the degree of familiarity with the non-technological requirements of Industry 4.0 relative to the age of the enterprise was performed (see Table 4.11).

Table 4.11. Pairwise multiple comparison of the degree of familiarity with the non-technological requirements of Industry 4.0 of the researched enterprises by their age

Sample 1 – Sample 2	Test statistics	Standard error y	Standardised test statistic	Significance	Adjusted significance[a]
Between 1 and 5 years – over 5 years to 10 years	– 5.794	14.936	– 0.388	0.698	1.000
Between 1 and 5 years – over 10 years to 15 years	– 35.920	12.257	– 2.930	0.003	0.020
Between 1 and 5 years – over 15 years	– 61.426	11.808	– 5.202	<0.001	0.000*
Over 5 years to 10 years – over 10 years to 15 years	– 30.125	12.257	– 2.458	0.014	0.084
Over 5 years to 10 years – over 15 years	– 55.632	11.808	– 4.711	<0.001	0.000*
Over 10 years to 15 years – over 15 years	– 25.507	8.160	– 3.126	0.002	0.011

Each row tests the null hypothesis that the distributions of Sample 1 and Sample 2 are the same.
Asymptotic significance is displayed (2-sided tests). The significance level is 0.05.
[a] Significance values were adjusted using the Bonferroni method.
* Statistically significant relationship.

Source: own elaboration.

The degree of familiarity with the non-technological requirements of Industry 4.0 is significantly higher in the oldest enterprises (over 15 years on the market) than the degree of familiarity with these requirements in the youngest enterprises (between 1 and 5 years on the market). In contrast, in the youngest enterprises (between 1 and 5 years on the market), the level of familiarity with non-technological Industry 4.0 requirements is significantly lower than in enterprises over 10 years to 15 years on the market. Otherwise, there are no grounds to reject the null hypothesis, as the differences are not statistically significant (see Figure 4.19).

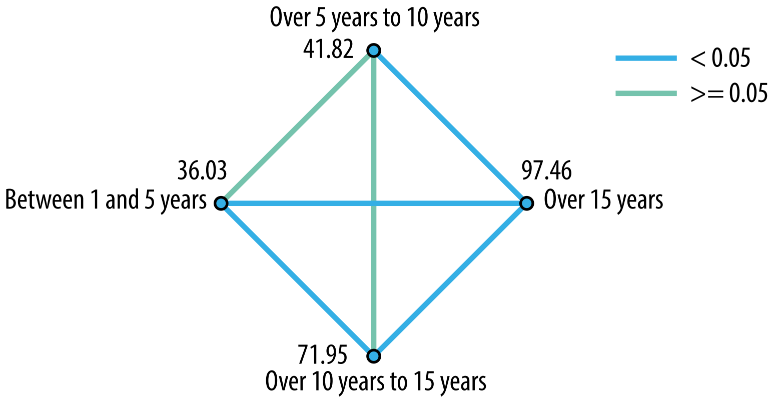

Figure 4.19. Pairwise multiple comparison of the degree of familiarity with the non-technological requirements of Industry 4.0 of the researched enterprises by their age

Source: own elaboration.

It was followed by an assessment of the degree of familiarity with the non-technological requirements of Industry 4.0 by the enterprises researched, considering the criterion of their size. The non-parametric Kruskal-Wallis test was also used to assess this relationship, as the one-factor variance analysis assumptions were not met. The results of the Kruskal-Wallis test (statistic value $H = 95.115$, $p < 0.001$) confirmed the existence of statistically significant differences between the analysed variables, i.e. the degree of familiarity with the non-technological requirements of Industry 4.0 and the size of the enterprise. To check between which enterprises these differences can be found, an analysis of the mean rank observations of the degree of familiarity with the non-technological requirements of Industry 4.0 was performed (see Table 4.12), which showed that statistically significant differences are to be expected between small and large enterprises.

Table 4.12. Mean ranks of the degree of familiarity with the non-technological requirements of Industry 4.0 of the researched enterprises by their size

Enterprise size	N	Mean rank
Small enterprise	104	52.88
Medium enterprise	37	123.99
Large enterprise	10	138.90
Total	151	

Source: own elaboration.

To test whether the differences are significant, a pairwise multiple comparison analysis of the degree of familiarity with the non-technological requirements of Industry 4.0 relative to the size of the enterprise was performed (see Table 4.13), which showed that statistically significant differences between small and large enterprises are to be expected.

Table 4.13. Pairwise multiple comparison of the degree of familiarity with non-technological Industry 4.0 requirements of the researched enterprises by their size

Sample 1 – Sample 2	Test statistics	Standard error y	Standardised test statistic	Significance	Adjusted significance[a]
Small enterprise – Medium enterprise	–71.107	8.336	–8.531	0.000	0.000*
Small enterprise – Large enterprise	–86.020	14.417	–5.967	<0.001	0.000*
Medium enterprise – Large enterprise	–14.914	15.520	–0.961	0.337	1.000

Each row tests the null hypothesis that the distributions of Sample 1 and Sample 2 are the same.
Asymptotic significance is displayed (2-sided tests). The significance level is 0.05.
[a] Significance values were adjusted using the Bonferroni method.
* Statistically significant relationship.

Source: own elaboration.

As previously expected, the degree of familiarity with Industry 4.0 non-technological requirements is significantly lower in small enterprises than the degree of familiarity with these requirements in medium and large enterprises. In contrast, the difference in the degree of familiarity with Industry 4.0 non-technological requirements in medium and large enterprises is not statistically significant, as illustrated in Figure 4.20.

In the next stage of the analysis, an attempt was made to answer whether there was a relationship between the scope to which Industry 4.0 technologies were applied and selected enterprise characteristics (age and size). To this end, the SISAI4.0T was calculated for each enterprise, which is the sum of the respondents' scores on the 17 types of technology characteristic of Industry 4.0[382]. This indicator can take values from 17 to 85[383], and the higher the level, the larger the scope to which the research enterprise applies Industry 4.0 technologies.

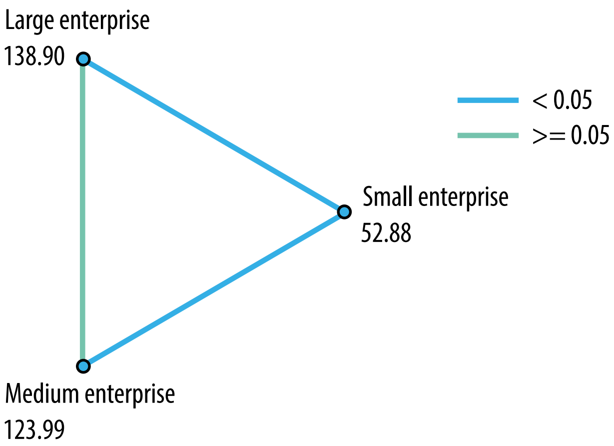

Figure 4.20. Pairwise multiple comparison of the degree of familiarity with Industry 4.0 technologies of the enterprises researched by their size

Source: own elaboration.

Next, the researched enterprises' scope of application of Industry 4.0 technologies was assessed concerning age. The non-parametric Kruskal-Wallis test was used to determine this relationship, as the assumptions for using one-way analysis of variance (ANOVA – Analysis Of Variance) were also not met. The results of the Kruskal-Wallis test (statistic value $H = 17.876$, $p < 0.001$) confirmed the existence of statistically significant differences between the analysed variables, i.e. the scope of application of Industry 4.0 technologies and the age of the enterprise. To check between which enterprises these differences can be found, an analysis of the mean rank observations of the scope of application of Industry 4.0 technology was performed (see Table 4.14), which showed that statistically significant differences are to be expected between the youngest enterprises (1 to 5 years on the market) and the oldest enterprises (more than 15 years on the market).

382 For a detailed analysis of the types of Industry 4.0 technologies, see subchapter 4.1.

383 Due to the design of the questionnaire, respondents' answers were assigned points ranging from 1–5, which in this case gives a minimum value of 17 and a maximum value of 85.

Table 4.14. Mean ranks of the scope of application of Industry 4.0 technologies of the researched enterprises by their age

Age of enterprise	N	Mean rank
Between 1 and 5 years	17	51.06
Over 5 years to 10 years	17	64.91
Over 10 years to 15 years	49	67.23
Over 15 years	68	91.32
Total	151	

Source: own elaboration.

To test whether the remaining differences are significant, a pairwise multiple comparison analysis of the scope of application of Industry 4.0 technologies relative to the age of the enterprise was performed (see Table 4.15).

Table 4.15. Pairwise multiple comparison of the scope of application of Industry 4.0 technologies of the researched enterprises by their age

Sample 1 – Sample 2	Test statistics	Standard error y	Standardised test statistic	Significance	Adjusted significance[a]
Between 1 and 5 years – over 5 years to 10 years	– 13.853	14.602	– 0.949	0.343	1.000
Between 1 and 5 years – over 10 years to 15 years	– 16.176	11.983	– 1.350	0.177	1.000
Between 1 and 5 years – over 15 years	– 40.265	11.544	– 3.488	<0.001	0.003*
Over 5 years to 10 years – over 10 years to 15 years	– 2.323	11.983	– 0.194	0.846	1.000
Over 5 years to 10 years – over 15 years	– 26.412	11.544	– 2.288	0.022	0.133
Over 10 years to 15 years – over 15 years	– 24.089	7.977	– 3.020	0.003	0.015

Each row tests the null hypothesis that the distributions of Sample 1 and Sample 2 are the same.
Asymptotic significance is displayed (2-sided tests). The significance level is 0.05.
[a] Significance values were adjusted using the Bonferroni method.
* Statistically significant relationship.

Source: own elaboration.

The analysis shows that the scope of application of Industry 4.0 technologies is larger in the oldest enterprises (over 15 years on the market) than in the youngest enterprises (between 1 and 5 years on the market). In other cases, there are no grounds to reject the null hypothesis, as the differences between the analysed variables are not statistically significant (see Figure 4.21).

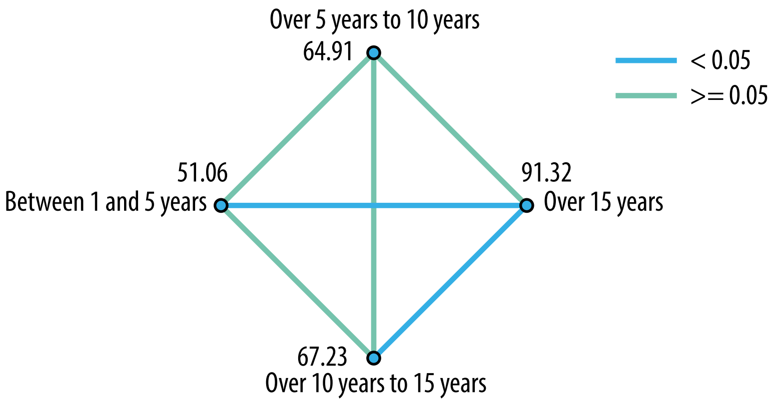

Figure 4.21. Pairwise multiple comparison of the scope of application of Industry 4.0 technologies of the researched enterprises by their age

Source: own elaboration.

In the following research stage, the scope to which Industry 4.0 technologies were applied by the enterprises surveyed was assessed considering their size. The non-parametric Kruskal-Wallis test was also used to determine this relationship, as the one-factor variance analysis assumptions were not met. The results of the Kruskal-Wallis test (statistic value H = 102.391, $p < 0.001$) confirmed the existence of statistically significant differences between the analysed variables, i.e. the scope of application of Industry 4.0 technologies and the size of the enterprise. To check between which enterprises these differences could be found, an analysis of the mean rank observations of the scope of application of Industry 4.0 technologies was performed (see Table 4.16), which showed that statistically significant differences between small and large enterprises should be expected.

Table 4.16. Mean ranks of the scope of application of Industry 4.0 technologies of the researched enterprises by their size

Enterprise size	N	Mean rank
Small enterprise	104	52.63
Medium enterprise	37	123.45
Large enterprise	10	143.45
Total	151	

Source: own elaboration.

To test whether the remaining differences are significant, a pairwise multiple comparison analysis of the scope to which Industry 4.0 technologies are being applied relative to the size of the enterprise was performed (see Table 4.17).

Table 4.17. Pairwise multiple comparison of the scope of application of Industry 4.0 technologies of the researched enterprises by their size

Sample 1 – Sample 2	Test statistics	Standard error y	Standardised test statistic	Significance	Adjusted significance[a]
Small enterprise – Medium enterprise	– 70.811	8.149	– 8.690	0.000	0.000*
Small enterprise – Large enterprise	– 90.815	14.095	– 6.443	<0.001	0.000*
Medium enterprise – Large enterprise	– 20.004	15.173	– 1.318	0.187	0.562

Each row tests the null hypothesis that the distributions of Sample 1 and Sample 2 are the same.
Asymptotic significance is displayed (2-sided tests). The significance level is 0.05.
[a] Significance values were adjusted using the Bonferroni method.
* Statistically significant relationship.

Source: own elaboration.

As expected earlier, the scope of application of Industry 4.0 technologies is significantly lower in small enterprises than in medium and large enterprises. In contrast, the difference in the scope of application of Industry 4.0 technologies in medium and large enterprises is not statistically significant, as shown in Figure 4.22.

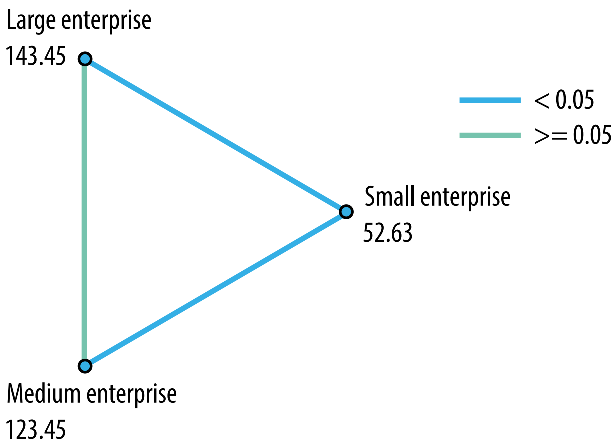

Figure 4.22. Pairwise multiple comparison of the scope of application of Industry 4.0 technologies of the researched enterprises by their size
Source: own elaboration.

In the next stage of the analysis, an attempt was made to answer the question of whether there is a relationship between the scope to which non-technological Industry 4.0 requirements are applied and the selected characteristics of the enterprise (age and size). For this purpose, a SISANTRI4.0 was calculated for the analysis for each enterprise, which is the sum of the respondents' evaluation scores of 15 of these requirements[384]. The value of this indicator ranges from 15 to 75[385], and the higher its level, the larger the scope of application of non-technological Industry 4.0 requirements by the enterprise researched.

The scope to which non-technological Industry 4.0 requirements were applied by the enterprises surveyed was then assessed concerning age. The non-parametric Kruskal-Wallis test was also used to determine this relationship, as the assumptions for using one-way analysis of variance (ANOVA – Analysis Of Variance) were not met. The results of the Kruskal-Wallis test (statistic value $H = 38.252$, $p < 0.001$) confirmed the existence of statistically significant differences between the analysed variables, i.e. the scope of application of non-technological Industry 4.0 requirements and the age of the enterprise. To check between which enterprises these differences can be found, an analysis of the mean rank observations of the scope of application of Industry 4.0 non-technological requirements was performed (see Table 4.18), which showed that statistically significant differences are to be expected between the youngest enterprises (1 to 5 years on the market) and the oldest enterprises (more than 15 years on the market).

Table 4.18. Mean ranks of the scope of application of non-technological Industry 4.0 requirements of the researched enterprises by their age

Age of enterprise	N	Mean rank
Between 1 and 5 years	17	38.59
Over 5 years to 10 years	17	41.50
Over 10 years to 15 years	49	72.70
Over 15 years	68	96.35
Total	151	

Source: own elaboration.

To test whether the remaining differences are significant, a pairwise multiple comparison analysis of the scope of application of Industry 4.0 non-technological requirements relative to the age of the enterprise was performed (see Table 4.19).

The scope of application of non-technological Industry 4.0 requirements is significantly larger in the oldest enterprises (over 15 years on the market) than the scope of application of these requirements in the youngest enterprises (between 1 and 5 years on the market) and in enterprises over 5 years to 10 years on the market. In other cases,

384 For a detailed analysis of the dimensions describing the non-technological requirements of Industry 4.0, see subchapter 4.1.

385 Due to the design of the questionnaire, respondents' answers were assigned points ranging from 1–5, which in this case gives a minimum value of 15 and a maximum value of 75.

there are no grounds to reject the null hypothesis, as the differences between the analysed variables are not statistically significant (see Figure 4.23).

Table 4.19. Pairwise multiple comparison of the scope of application of non-technological Industry 4.0 requirements of the researched enterprises by their age

Sample 1 – Sample 2	Test statistics	Standard error y	Standardised test statistic	Significance	Adjusted significance[a]
Between 1 and 5 years – over 5 years to 10 years	– 5.794	14.936	– 0.388	0.698	1.000
Between 1 and 5 years – over 10 years to 15 years	– 35.920	12.257	– 2.930	0.003	0.020
Between 1 and 5 years – over 15 years	– 61.426	11.808	– 5.202	<0.001	0.000*
Over 5 years to 10 years – over 10 years to 15 years	– 30.125	12.257	– 2.458	0.014	0.084
Over 5 years to 10 years – over 15 years	– 55.632	11.808	– 4.711	<0.001	0.000*
Over 10 years to 15 years – over 15 years	– 25.507	8.160	– 3.126	0.002	0.011

Each row tests the null hypothesis that the distributions of Sample 1 and Sample 2 are the same.
Asymptotic significance is displayed (2-sided tests). The significance level is 0.05.
[a] Significance values were adjusted using the Bonferroni method.
* Statistically significant relationship.

Source: own elaboration.

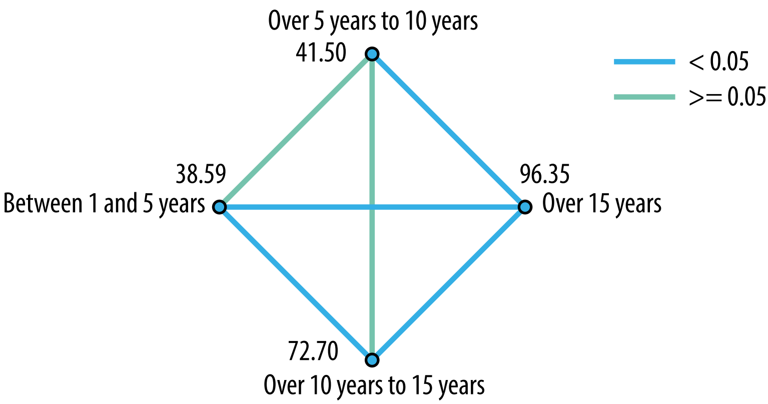

Figure 4.23. Pairwise multiple comparison of the scope of application of non-technological Industry 4.0 requirements of the researched enterprises by their age

Source: own elaboration.

Continuing the analysis, the scope to which the enterprises applied the non-technological requirements of Industry 4.0 researched, considering their size, was assessed. The non-parametric Kruskal-Wallis test was also used to determine this relationship, as the one-factor variance analysis assumptions were not met. The results of the Kruskal-Wallis test (statistic value H = 91.918, $p < 0.001$) confirmed the existence of statistically significant differences between the analysed variables, i.e. the scope of application of non-technological Industry 4.0 requirements and the size of the enterprise. A mean rank observation analysis was performed to check which enterprises these differences can be found (see Table 4.20), which showed that statistically significant differences between small and large enterprises are to be expected.

Table 4.20. Mean ranks of the scope of application of non-technological Industry 4.0 requirements of the researched enterprises by their size

Enterprise size	N	Mean rank
Small enterprise	104	53.23
Medium enterprise	37	123.41
Large enterprise	10	137.40
Total	151	

Source: own elaboration.

To test whether the differences are significant, a pairwise multiple comparison analysis of the scope of application of Industry 4.0 non-technological requirements relative to the size of the enterprise was performed (see table 4.21), which showed that statistically significant differences are to be expected between small and large enterprises.

Table 4.21. Pairwise multiple comparison of the scope of application of non-technological Industry 4.0 requirements of the researched enterprises by their size

Sample 1 – Sample 2	Test statistics	Standard error y	Standardised test statistic	Significance	Adjusted significance[a]
Small enterprise – Medium enterprise	– 70.175	8.347	– 8.407	0.000	0.000*
Small enterprise – Large enterprise	– 84.169	14.437	– 5.830	<0.001	0.000*
Medium enterprise – Large enterprise	– 13.995	15.541	– 0.900	0.368	1.000

Each row tests the null hypothesis that the distributions of Sample 1 and Sample 2 are the same.
Asymptotic significance is displayed (2-sided tests). The significance level is 0.05.
[a] Significance values were adjusted using the Bonferroni method.
* Statistically significant relationship.

Source: own elaboration.

As previously expected, the scope of application of non-technological Industry 4.0 requirements is significantly lower in small enterprises than in medium and large enterprises. In contrast, the difference in the scope of application of non-technological Industry 4.0 requirements in medium and large enterprises is not statistically significant, as illustrated in Figure 4.24.

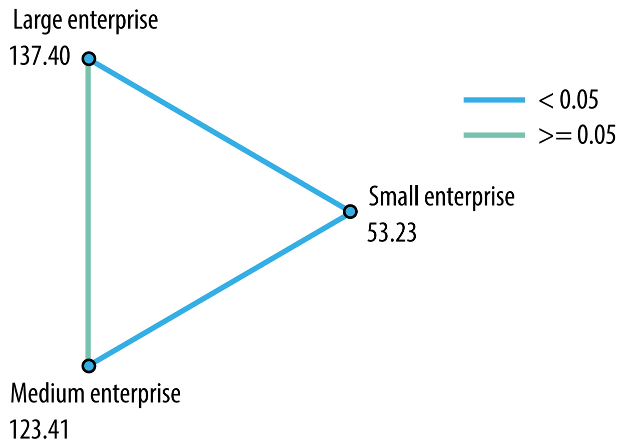

Figure 4.24. Pairwise multiple comparison of the scope of application of non-technological Industry 4.0 requirements of the researched enterprises by their size

Source: own elaboration.

It was followed by an assessment of the differentiation in the level of development of the technological potential of the enterprises surveyed concerning age and size. To assess the level of development of the technological potential of the researched enterprises, the SITP was created, which is the sum of the respondents' scores in the six areas describing this potential. This indicator ranges from 6 to 30[386], and the higher its value, the higher the level of development of the technological potential of the surveyed enterprise. ANOVA analysis of variance was used as the research method, as the assumptions for using this analysis were met. The research on the distribution of the analysed variables showed, based on descriptive characteristics (asymmetry, kurtosis, M-estimators, Etc.), that the given distribution could be considered close in shape to a normal distribution (see Table 4.22).

386 Due to the design of the questionnaire, respondents' answers were assigned points ranging from 1–5, which in this case gives a minimum value of 6 and a maximum value of 30.

Table 4.22. Descriptive statistics and M-estimators for SITP

			Statistic	Std. Error
SITP	Mean		16.76	0.420
	95% Confidence Interval for Mean	Lower Bound	15.93	
		Upper Bound	17.59	
	5% Trimmed Mean		16.66	
	Median		15.00	
	Variance		26.663	
	Std. Deviation		5.164	
	Minimum		6	
	Maximum		30	
	Range		24	
	Interquartile Range		8	
	Skewness		0.610	0.197
	Kurtosis		– 0.384	0.392

M-Estimators				
	Huber's M-Estimator[a]	Tukey's Biweight[b]	Hampel's M-Estimator[c]	Andrews' Wave[d]
SITP	15.34	14.35	15.27	14.32

[a] The weighting constraints 1.339.
[b] The weighting constraints 4.685.
[c] The weighting constraints are 1.700, 3.400, and 8.500.
[d] The weighting constraints 1.349 π.

Source: own elaboration.

The research carried out showed that there is a statistically significant differentiation in the level of development of the technological potential of enterprises by the age of the enterprise (see Figure 4.25).

To test the assumption of homogeneity of variances, this research used Levene's test (F = 14.73, $p < 0.001$), which does not allow the assumption of the equality of variances. In this situation, a strong test of equality of means, the Welch test (F = 13.719, $p < 0.001$), can be used to assess the significance of differences between the mean level of development of technological potential, which indicates that there are statistically significant differences between the level of development of an enterprise's technological potential and its age. Determining which mean is significantly different from the others requires multiple comparison tests (post-hoc tests). The unfulfilled assumption of the equality of variance allows the use of Tamhane's T2 test, among others, for this purpose. The results of the analyses are presented in Table 4.23. The level of development of technological potential differs most between enterprises operating on the market for more than 15 years and those existing for less time. Thus, the age of the enterprise is a factor that differentiates the level of development of technological potential.

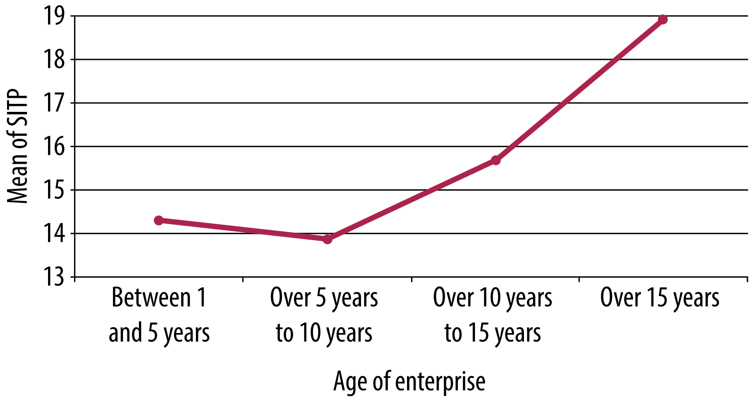

Figure 4.25. Differentiation of the level of development of the technological potential of the researched enterprises by their age

Source: own elaboration.

Table 4.23. Pairwise multiple comparison of the mean level of development of the technological potential of the enterprises researched by their age (Tamhane Test)

(I) Age of enterprise	(J) Age of enterprise	Mean Difference (I – J)	Std. Error	Sig.
Between 1 and 5 years	Over 5 years to 10 years	0.412	1.028	0.999
	Over 10 years to 15 years	– 1.420	0.685	0.229
	Over 15 years	– 4.559*	0.727	<0.001
Over 5 years to 10 years	Between 1 and 5 years	– 0.412	1.028	0.999
	Over 10 years to 15 years	– 1.832	1.188	0.576
	Over 15 years	– 4.971*	1.213	0.002
Over 10 years to 15 years	Between 1 and 5 years	1.420	0.685	0.229
	Over 5 years to 10 years	1.832	1.188	0.576
	Over 15 years	– 3.139*	0.940	0.007
Over 15 years	Between 1 and 5 years	4.559*	0.727	<0.001
	Over 5 years to 10 years	4.971*	1.213	0.002
	Over 10 years to 15 years	3.139*	0.940	0.007

* The mean difference is significant at the 0.05 level.

Source: own elaboration.

The research further indicated that there is a statistically significant differentiation in the level of development of an enterprise's technological potential due to its size (see Figure 4.26). To test the assumption of homogeneity of variances, this research used Levene's test ($F = 0.228$, $p = 0.796$), which allows the assumption of the equality of variances. In this situation, a one-way ANOVA analysis of variance can be used to assess the significance of differences in the level of development of the technological potential of enterprises according to their size. The research results (F = 320.086, $p < 0.001$) indicated statistically significant differences between the mean level of technological potential development of an enterprise by size.

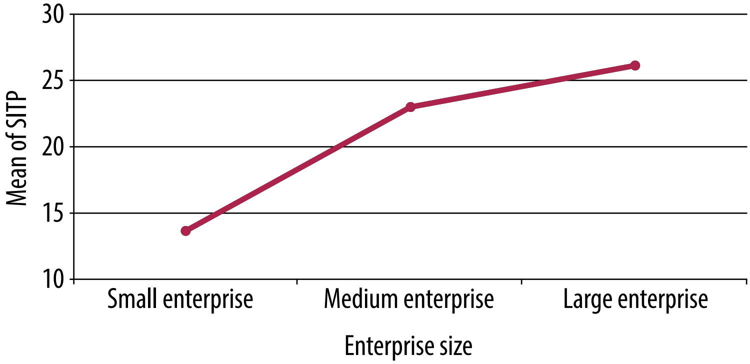

Figure 4.26. Differentiation of the level of development of the technological potential of the researched enterprises by their size

Source: own elaboration.

Determining which mean is significantly different from the others requires multiple comparison tests (post-hoc tests). These methods make it possible to group the means and extract homogeneous groups, i.e. groups of means that are not statistically different. The fulfilled assumption of the equality of variance allows the Bonferroni test, among others, to be used for this purpose. The results of the analyses are presented in Table 4.24. Thus, the mean level of development of technological potential differs most between large enterprises and small and medium ones, but also between medium and small ones.

Next, the relationship between the intensity of application and type of technology applied (basic, core and emerging) and the age of the enterprise was assessed (see Table 4.25).

To test this relationship, Fisher's exact test was used[387]. If the relationship between the variables proved to be statistically significant in the next step, Kendall's tau-c coefficient was used to assess the strength of the relationship due to the ordinal level of measurement of the variables. The test results indicated a statistically significant relationship between the intensity of technology application and the age of the enterprise. The direction of the correlation for the three types of technologies is positive, meaning that the longer the enterprise has been operating in the market, the more intensively

387 Fisher's exact test was used because the condition for using the chi-square test of independence was not met, not all expected counts in all cells of the contingency table were greater than or equal to 5.

it uses all the technology indicated for assessment. However, the strength of the relationship, as measured by Kendall's tau-c coefficient for all technologies, is weak.

Table 4.24. Pairwise multiple comparison of the mean level of development of the technological potential of the enterprises researched by their size (Bonferroni Test)

(I) Enterprise size	(J) Enterprise size	Mean Difference (I – J)	Std. Error	Sig.
Small enterprise	Medium enterprise	– 9.209*	0.431	< 0.001
	Large enterprise	– 12.417*	0.746	< 0.001
Medium enterprise	Small enterprise	9.209*	0.431	< 0.001
	Large enterprise	– 3.208*	0.803	< 0.001
Large enterprise	Small enterprise	12.417*	0.746	< 0.001
	Medium enterprise	3.208*	0.803	< 0.001

* The mean difference is significant at the 0.05 level.

Source: own elaboration.

Table 4.25. Assessment of the relationship between the intensity of application of technologies and the age of the enterprises researched

Variable	Fisher's statistics	df	Asymptotic/ exact significance (2-sided)	Kendall's Tau-c coefficient	Exact significance (2-sided)
Basic Technologies					
Age of enterprise	36.822*	12	0.001**	0.229	0.001**
Core Technologies					
Age of enterprise	38.567*	12	0.001**	0.291	0.001**
Emerging Technologies					
Age of enterprise	27.363*	12	0.001**	0.291	0.001**

* Unfulfilled assumption of the chi-square test of independence, so that the expected numbers in all cells of the contingency table are greater than or equal to 5.
** Statistically significant relationship (α = 0.001).

Source: own elaboration.

In the next step, the relationship between the intensity of application of the types of technology (basic, core and emerging) for the research undertaken and the size of the enterprise was assessed (see Table 4.26).

The research results indicate a statistically significant, positive and significant relationship between the intensity of technology application and the size of the enterprise. The direction of the correlation for the three analysed types of technologies is positive, which means that the larger the enterprise, the more intensively it applies all the indicated types of technologies. Notably, the strength of the relationship as measured by

Kendall's tau-c coefficient for all technologies is moderate, and the value of Kendall's tau-c coefficient is increasingly higher as the size of the enterprise increases.

Table 4.26. Assessment of the relationship between the intensity of application of technologies and the size of the enterprises researched

Variable	Fisher's statistics	df	Asymptotic/ exact significance (2-sided)	Kendall's Tau-c coefficient	Exact significance (2-sided)
Basic Technologies					
Enterprise size	150.4*	8	0.001**	0.645	0.001**
Core Technologies					
Enterprise size	165.46*	8	0.001**	0.661	0.001**
Emerging Technologies					
Enterprise size	174.47*	8	0.001**	0.672	0.001**

* Unfulfilled assumption of the chi-square test of independence, so that the expected numbers in all cells of the contingency table are greater than or equal to 5.
** Statistically significant relationship (α = 0.001).

Source: own elaboration.

In the next step, the relationship between the intensity of occurrence of various forms of R&D activity and the age of the enterprise was assessed (see Table 4.27).

The research showed a statistically significant relationship between the intensity of occurrence of various forms of R&D activity and the age of the enterprise. The direction of the correlation for all forms of R&D activity is positive, which means that the longer the enterprise has been operating on the market, the higher the intensity of occurrence of various forms of R&D activity. However, the strength of the relationship, as measured by Kendall's tau-c coefficient for all forms of R&D activity, is weak.

Table 4.27. Assessment of the relationship between the intensity of occurrence of various forms of R&D activity and the age of the enterprises researched

Variable	Fisher's statistics	df	Asymptotic/ exact significance (2-sided)	Kendall's Tau-c coefficient	Exact significance (2-sided)
Conducting R&D activities					
Age of enterprise	27.91*	12	0.001**	0.295	0.001**
Development of R&D infrastructure					
Age of enterprise	29.57*	12	0.001**	0.293	0.001**
Investment in R&D activity					
Age of enterprise	28.771*	12	0.001**	0.288	0.001**

Variable	Fisher's statistics	df	Asymptotic/ exact significance (2-sided)	Kendall's Tau-c coefficient	Exact significance (2-sided)
Development of R&D employees					
Age of enterprise	33.52*	9	0.001**	0.302	0.001**
Cooperation with external R&D centers e.g. universities					
Age of enterprise	29.152*	12	0.001**	0.301	0.001**

* Unfulfilled assumption of the chi-square test of independence, so that the expected numbers in all cells of the contingency table are greater than or equal to 5.
** Statistically significant relationship (α = 0.001).

Source: own elaboration.

The relationship between the intensity of occurrence of various forms of R&D activity and the size of the enterprise was then assessed (see Table 4.28).

The research results indicate a statistically significant relationship between the intensity of occurrence of various forms of R&D activity and the size of the enterprise. The direction of correlation for all forms of R&D activity is positive, which means that the larger the enterprise, the higher the intensity of occurrence of various forms of R&D activity. It is worth noting that the strength of the correlation measured by Kendall's tau-c coefficient for all forms of R&D activity is moderate.

Table 4.28. Assessment of the relationship between the intensity of occurrence of various forms of R&D activity and the size of the enterprises researched

Variable	Fisher's statistics	df	Asymptotic/ exact significance (2-sided)	Kendall's Tau-c coefficient	Exact significance (2-sided)
Conducting R&D activities					
Enterprise size	175.23*	8	0.001**	0.669	0.001**
Development of R&D infrastructure					
Enterprise size	175.95*	8	0.001**	0.668	0.001**
Investment in R&D activity					
Enterprise size	176.29*	8	0.001**	0.666	0.001**
Development of R&D employees					
Enterprise size	176.13*	6	0.001**	0.661	0.001**
Cooperation with external R&D centers e.g. universities					
Enterprise size	168.37*	8	0.001**	0.643	0.001**

* Unfulfilled assumption of the chi-square test of independence, so that the expected numbers in all cells of the contingency table are greater than or equal to 5.
** Statistically significant relationship (α = 0.001).

Source: own elaboration.

The next stage of the analysis attempted to answer whether there is a relationship between the level of competitive advantage of the enterprises under study and their selected characteristics (age and size). For this purpose, a SILCA was calculated for the analysis of each enterprise, which is the sum of the respondents' evaluation scores of 10 factors describing the enterprise's competitiveness[388]. This indicator ranges from 10 to 50[389], and the higher its value, the higher the level of competitive advantage of the researched enterprise.

The following analysis stage assessed the enterprise's competitive advantage level concerning age. The non-parametric Kruskal-Wallis test was also used to determine this relationship, as the assumptions for the use of a one-factor analysis of variance were not met. The results of the Kruskal-Wallis test (statistic value $H = 10.045$, $p < 0.05$) confirmed the existence of statistically significant differences between the analysed variables, i.e. the level of competitive advantage and the age of the enterprise. To check between which enterprises these differences could be found, an analysis of the mean rank observations of the level of competitive advantage was performed (see Table 4.29), which showed that statistically significant differences should be expected between the youngest enterprises (1 to 5 years on the market) and the oldest enterprises (more than 15 years on the market).

Table 4.29. Mean ranks of the level of competitive advantage of the enterprises researched by their age

Age of enterprise	N	Mean rank
Between 1 and 5 years	17	67.53
Over 5 years to 10 years	17	64.24
Over 10 years to 15 years	49	65.85
Over 15 years	68	88.38
Total	151	

Source: own elaboration.

A pairwise multiple comparison analysis of the level of competitive advantage relative to the age of the enterprise was carried out to test whether the remaining differences were significant (see Table 4.30).

388 For a detailed analysis of the factors describing the enterprise's competitiveness, see subchapter 4.1.

389 Due to the design of the questionnaire, respondents' answers were assigned points ranging from 1–5, which in this case gives a minimum value of 10 and a maximum value of 50.

Table 4.30. Pairwise multiple comparison of the level of competitive advantage of the enterprises researched by their age

Sample 1 – Sample 2	Test statistics	Standard error y	Standardised test statistic	Significance	Adjusted significance[a]
Over 5 years to 10 years – over 10 years to 15 years	– 1.612	12.254	– 0.132	0.895	1.000
Over 5 years to 10 years – between 1 and 5 years	3.294	14.932	0.221	0.825	1.000
Over 5 years to 10 years – over 15 years	– 24.140	11.805	– 2.045	0.041	0.245
Over 10 years to 15 years – between 1 and 5 years	1.682	12.254	0.137	0.891	1.000
Over 10 years to 15 years – over 15 years	– 22.528	8.158	– 2.762	0.006	0.035
Between 1 and 5 years – over 15 years	– 20.846	11.805	– 1.766	0.077	0.465

Each row tests the null hypothesis that the distributions of Sample 1 and Sample 2 are the same.
Asymptotic significance is displayed (2-sided tests). The significance level is 0.05.
[a] Significance values were adjusted using the Bonferroni method.

Source: own elaboration.

The level of competitive advantage is significantly lower in enterprises operating in the market over 10 to 15 years than in the oldest enterprises (over 15 years on the market). In other cases, there are no grounds to reject the null hypothesis, as the differences between the analysed variables are not statistically significant (see Figure 4.27).

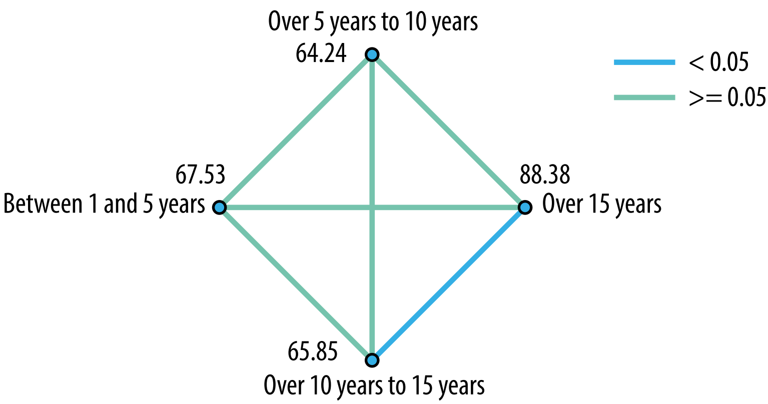

Figure 4.27. Pairwise multiple comparison of the level of competitive advantage of the enterprises researched by their age

Source: own elaboration.

The level of the enterprise's competitive advantage relative to its size was then assessed. The non-parametric Kruskal-Wallis test was also used to determine this relationship, as the one-factor variance analysis assumptions were not met. The results of the Kruskal-Wallis test (statistic value H = 91.903, $p < 0.001$) confirmed the existence of statistically significant differences between the analysed variables, i.e. the level of competitive advantage and the size of the enterprise. To check between which enterprises these differences could be found, an analysis of the mean rank observations of the level of competitive advantage was carried out (see Table 4.31), which showed that statistically significant differences should be expected between small and large enterprises.

Table 4.31. Mean ranks of the level of competitive advantage of the enterprises researched by their size

Enterprise size	N	Mean rank
Small enterprise	104	53.29
Medium enterprise	37	122.93
Large enterprise	10	138.50
Total	151	

Source: own elaboration.

A pairwise multiple comparison analysis of the level of competitive advantage relative to the size of the enterprise was carried out to test whether the remaining differences were significant (see Table 4.32).

Table 4.32. Pairwise multiple comparison of the level of competitive advantage of the enterprises researched by their size

Sample 1 – Sample 2	Test statistics	Standard error y	Standardised test statistic	Significance	Adjusted significance[a]
Small enterprise – Medium enterprise	– 69.639	8.334	– 8.356	0.000	0.000
Small enterprise – Large enterprise	– 85.207	14.414	– 5.912	<0.001	0.000
Medium enterprise – Large enterprise	– 15.568	15.516	– 1.003	0.316	0.947

Each row tests the null hypothesis that the distributions of Sample 1 and Sample 2 are the same.
Asymptotic significance is displayed (2-sided tests). The significance level is 0.05.
[a] Significance values were adjusted using the Bonferroni method.

Source: own elaboration.

The level of competitive advantage is significantly lower in small enterprises than in large and medium enterprises. In contrast, the difference in the level of competitive advantage in medium and large enterprises is not statistically significant, as shown in Figure 4.28.

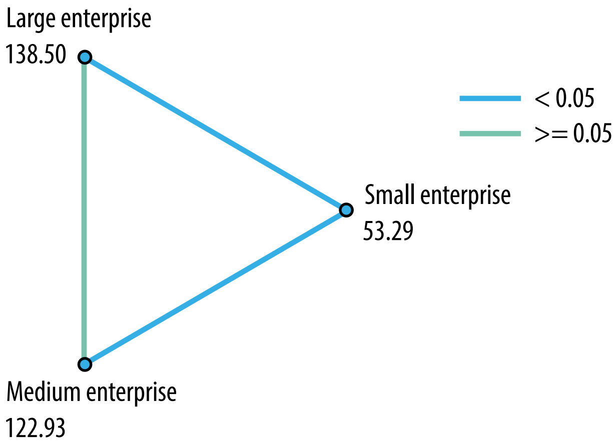

Figure 4.28. Pairwise multiple comparison of the level of competitive advantage of the enterprises researched by their size

Source: own elaboration.

Another area of research was an attempt to answer whether there is a relationship between the current competitive position of the surveyed enterprises and their selected characteristics (age and size). For this purpose, a CCP was calculated for the analysis of each enterprise, which is the sum of the respondents' evaluation scores of four meters of the enterprise's competitive position[390]. This indicator ranges from 4 to 20[391], and the higher its value, the higher the current competitive position of the enterprise under research. This indicator was then analysed concerning the age of the enterprises surveyed. The non-parametric Kruskal-Wallis test was also used to assess this relationship, as the one-factor variance analysis assumptions were not met. The results of the Kruskal-Wallis test (statistic value H = 17.886, $p < 0.05$) confirmed the existence of statistically significant differences between the analysed variables, i.e. the current competitive position and the age of the enterprise. To check between which enterprises these differences can be found, an analysis of the mean rank observations of the current competitive position was performed (see Table 4.33), which showed that statistically significant differences are to be expected between the youngest enterprises (1 to 5 years on the market) and the oldest enterprises (more than 15 years on the market).

390 For a detailed analysis of the meters of the competitive position of the surveyed enterprises, see subchapter 4.1.

391 Due to the design of the questionnaire, respondents' answers were assigned points ranging from 1–5, which in this case gives a minimum value of 4 and a maximum value of 20.

Table 4.33. Mean ranks of the current competitive position of the enterprises researched by their age

Age of enterprise	N	Mean rank
Between 1 and 5 years	17	43.71
Over 5 years to 10 years	17	59.53
Over 10 years to 15 years	49	79.70
Over 15 years	68	85.52
Total	151	

Source: own elaboration.

To check whether the remaining differences are significant, a pairwise multiple comparison analysis of the current competitive position relative to the age of the enterprise was performed (see Table 4.34).

Table 4.34. Pairwise multiple comparison of the current competitive position of the enterprises researched by their age

Sample 1 – Sample 2	Test statistics	Standard error y	Standardised test statistic	Significance	Adjusted significance[a]
Over 5 years to 10 years – over 10 years to 15 years	– 15.824	13.854	– 1.142	0.253	1.000
Over 5 years to 10 years – between 1 and 5 years	– 35.998	11.369	– 3.166	0.002	0.009
Over 5 years to 10 years – over 15 years	– 41.816	10.952	– 3.818	<0.001	0.001
Over 10 years to 15 years – between 1 and 5 years	– 20.175	11.369	– 1.775	0.076	0.456
Over 10 years to 15 years – over 15 years	– 25.993	10.952	– 2.373	0.018	0.106
Between 1 and 5 years – over 15 years	– 5.818	7.569	– 0.769	0.442	1.000

Each row tests the null hypothesis that the distributions of Sample 1 and Sample 2 are the same.
Asymptotic significance is displayed (2-sided tests). The significance level is 0.05.
[a] Significance values were adjusted using the Bonferroni method.

Source: own elaboration.

The current competitive position is significantly lower in the enterprises with the youngest experience on the market (between 1 and 10 years) than the current competitive position of the oldest enterprises (over 15 years on the market). In other cases, there are no grounds to reject the null hypothesis, as the differences between the analysed variables are not statistically significant (see Figure 4.29).

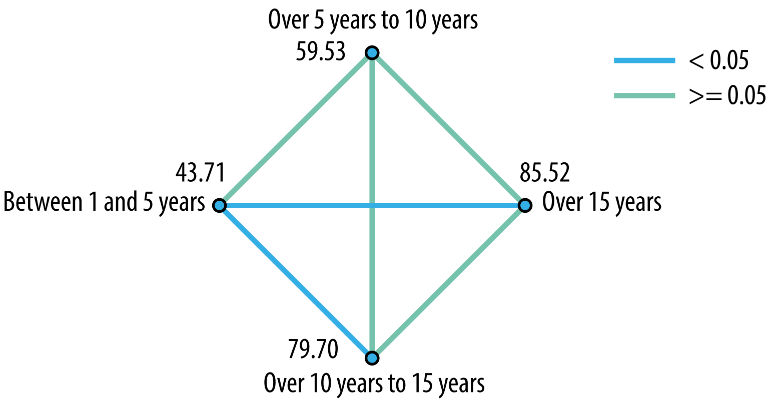

Figure 4.29. Pairwise multiple comparison of the current competitive position of the enterprises researched by their age

Source: own elaboration.

It was followed by assessing the enterprise's current competitive position relative to its size. The non-parametric Kruskal-Wallis test was also used to determine this relationship, as the one-factor variance analysis assumptions were not met. The results of the Kruskal-Wallis test (statistic value H = 37.076, $p < 0.001$) confirmed the existence of statistically significant differences between the analysed variables, i.e. current competitive position and enterprise size. To check between which enterprises these differences could be found, an analysis of the mean rank observations of the current competitive position was performed (see Table 4.35), which showed that statistically significant differences between small and large enterprises should be expected.

Table 4.35. Mean ranks of the current competitive position of the enterprises researched by their size

Enterprise size	N	Mean rank
Small enterprise	104	63.38
Medium enterprise	37	97.43
Large enterprise	10	127.90
Total	151	

Source: own elaboration.

To check whether the remaining differences are significant, a pairwise multiple comparison analysis of the current competitive position relative to the size of the enterprise was performed (see Table 4.36).

Table 4.36. Pairwise multiple comparison of the current competitive position of the enterprises researched by their size

Sample 1 – Sample 2	Test statistics	Standard error y	Standardised test statistic	Significance	Adjusted significance[a]
Small enterprise – Medium enterprise	– 34.048	7.732	– 4.404	<0.001	0.000
Small enterprise – Large enterprise	– 64.515	13.372	– 4.825	<0.001	0.000
Medium enterprise – Large enterprise	– 30.468	14.395	– 2.116	0.034	0.103

Each row tests the null hypothesis that the distributions of Sample 1 and Sample 2 are the same.
Asymptotic significance is displayed (2-sided tests). The significance level is 0.05.
[a] Significance values were adjusted using the Bonferroni method.

Source: own elaboration.

The current competitive position is significantly lower in small enterprises than in medium and large enterprises. In contrast, the difference in the current competitive position in medium and large enterprises is not statistically significant, as shown in Figure 4.30.

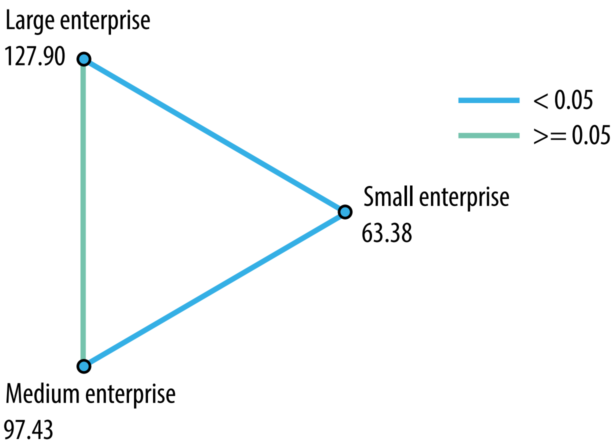

Figure 4.30. Pairwise multiple comparison of the current competitive position of the enterprises researched by their size
Source: own elaboration.

Summarising this part of the results, the degree of familiarity and scope of application of Industry 4.0 technologies and non-technological Industry 4.0 requirements are greater in large and longer-established enterprises. Knowledge and experience in successfully implementing Industry 4.0 technologies require time, financial, and human resources. It is more difficult for smaller enterprises to accumulate these promptly and use them efficiently. Larger enterprises are statistically more predisposed in this respect, enabling them to apply more advanced technological solutions. The technological potential development level is higher in large and longer-established enterprises. It means that technological potential requires enterprises to develop appropriate facilities. This process, unfortunately, requires time and resources. The technological advantage is, therefore, statistically more likely to be experienced by larger entities. On the other hand, when it comes to the intensity of technology application (basic, core and emerging), it is greater in large and longer-established enterprises. It shows that the more advanced the technology is, the more experience and capital are required. It directly correlates with the forms of R&D activity more common in larger enterprises that can afford the risks involved. They can also collaborate with others to pursue goals that would be impossible to achieve alone. Small enterprises in the market for a shorter time have the dilemma of using off-the-shelf solutions or trying to create their own. It is widespread to acquire technology from others, but this significantly impacts the lack of unique solutions that do not allow a high level of technological advantage and, thus, competitive advantage in the age of Industry 4.0. As far as the level of competitive advantage is concerned, it grows with the size of the enterprise, and its higher level can be observed in those with a longer time on the market. It shows that building the right image for an enterprise takes time, which allows it to create bonds with its customers. It is necessary to offer products and services of the highest quality while remaining attractive and differentiated. It is also essential to have the financial capacity to have a set of unique solutions and the ability to lead the market. Smaller enterprises have low capabilities but can gain experience from market-leading enterprises, e.g., inter-organisational cooperation. The exact relationship to the level of competitive advantage applies to the current competitive position. It shows that an established market position allows an enterprise to use its full potential to compete now and in the future. Larger and more experienced enterprises have a significant market share which enables them to gain an advantage against the performance of their competitors. The above analyses show that monitoring good practices using Industry 4.0 technologies in more extensive and experienced enterprises should be intensified. They can serve as inspiration and benchmarks for smaller and less experienced enterprises in this area, which can achieve higher levels of technological advantage and, thus, competitive advantage in the age of Industry 4.0.

4.3. Hypothesis testing

The next stage of the research focused on an in-depth analysis of the identified factors determining the level of development of the enterprise's technological potential and verification of hypothesis H1 that there is a relationship between the degree of familiarity with Industry 4.0 requirements and the level of development of the technological potential of the SMART enterprise's[392]. To test this relationship, the chi-square independence test was used[393]. If the relationship between the variables proved to be statistically significant in the next step, Kendall's tau-c coefficient was used to assess the strength of the relationship between the variables due to the ordinal level of measurement of the variables[394].

The analysis began by researching the relationship between SITP and the degree of familiarity with Industry 4.0 technologies in the enterprise under study (see Table 4.37).

Table 4.37. Assessment of the relationship between SITP and the degree of familiarity with Industry 4.0 technologies in the surveyed enterprises

Industry 4.0 technologies	Chi-square/ Fisher's statistics	df	Asymptotic/ exact significance (2-sided)	Kendall's Tau-c coefficient	Exact significance (2-sided)
Internet of Things, Internet of Services	257.455*	88	0.001**	**0.699**	0.001**
Cloud Computing	281.750*	88	0.001**	**0.677**	0.001**
Cybersecurity	197.818*	88	0.001**	**0.635**	0.001**
Robotisation	288.670*	88	0.001**	0.598	0.001**
Blockchain	238.900*	88	0.001**	0.589	0.001**
Information Network	248.700*	88	0.001**	0.587	0.001**
Mass Customisation	302.370*	88	0.001**	0.586	0.001**
Additive Manufacturing	235.450*	88	0.001**	0.585	0.001**
Radio Frequency Identification	250.750*	88	0.001**	0.581	0.001**
Cyber-Physical Systems	281.370*	88	0.001**	0.573	0.001**
M2M Communication	282.16*	88	0.001**	0.567	0.001**
Artificial Intelligence	226.080	88	0.001**	0.564	0.001**
Big Data Analytics	251.230*	88	0.001**	0.552	0.001**
Geolocalisation	229.960*	88	0.001**	0.547	0.001**
Neural Networks	194.038*	88	0.001**	0.546	0.001**
Virtual Reality, Augmented Reality	265.22*	88	0.001**	0.544	0.001**
Digital Twin	258.850*	88	0.001**	0.537	0.001**

* Unfulfilled assumption of the chi-square independence test, so that the expected counts in all cells of the contingency table are greater than or equal to 5.
** Statistically significant relationship (α = 0.001).

Source: own elaboration.

392 The SITP was used for the calculations and analysis is described in more detail in subchapter 4.2.
393 Broader described in chapter 3.
394 Broader described in chapter 3.

Analysis of the results showed statistically significant relationships between the degree of familiarity with technologies of the age of Industry 4.0 and the level of development of the technological potential of the SMART enterprise. The strength of the relationship, as measured by Kendall's tau-c coefficient, is moderate for all technologies. However, it is worth pointing out three Industry 4.0 technologies for which the correlation with the level of development of the enterprise's technological potential turned out to be the strongest, i.e., Internet of Things, Internet of Services (0.699), Cloud Computing (0.677) and Cybersecurity (0.635). Knowledge of these technologies has a statistically more significant impact on the level of development of an enterprise's SMART technological potential. These technologies are strongly interlinked, forming a base bundle of key technologies for development in the age of Industry 4.0. They are based on internet-based communications, distributed computing structures that enable remote data storage and processing, and the implementation of security measures to mitigate external and internal cyber threats. The bundle of these technologies is, therefore, the foundation for the infrastructure of an effective SMART enterprise in the age of Industry 4.0.

Continuing the analysis of this relationship, it was examined whether there was a relationship between SIDFI4.0T[395], and SITP. The analysis started by preparing a scatter plot of the analysed variables (see Figure 4.31).

Analysis of the scatter plot showed the linear character of the relationship, so Pearson's linear correlation coefficient was used to test it[396]. The correlation was statistically significant ($p < 0.001$), positive and significant $r = 0.814$, i.e. **the higher the degree of familiarity with Industry 4.0 technologies, the higher the technological potential development level**.

In the next stage of the analysis, the relationship between the degree of familiarity with the non-technological requirements of Industry 4.0 and the level of development of the technological potential in the enterprise under study (see Table 4.38).

395 Broader described in subchapter 4.2.

396 Broader described in chapter 3, compare with J. Wiktorowicz, M.M.Grzelak, K. Grzeszkiewicz-Radulska, *Analiza statystyczna…*

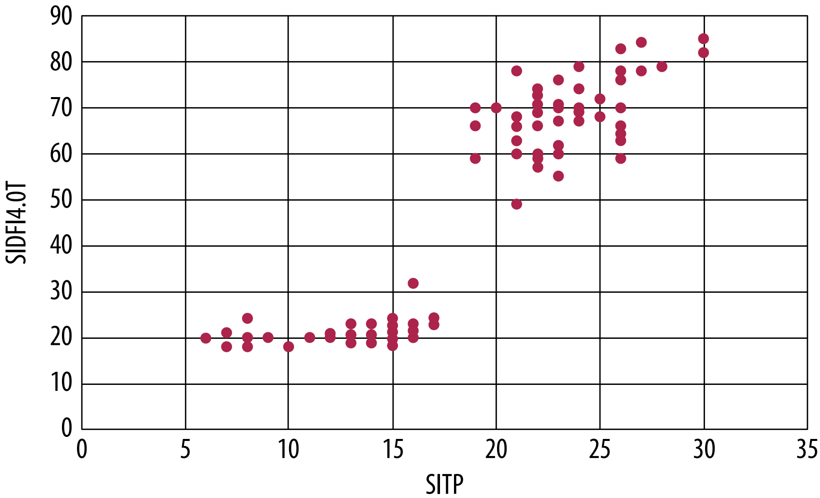

Figure 4.31. Scatter plot for variables SIDFI4.0T and SITP

Source: own elaboration.

All non-technological Industry 4.0 requirements in the enterprise show a statistically significant relationship with the level of development of the SMART enterprise's technological potential. The strength of the relationship, as measured by Kendall's tau-c coefficient, is at least moderate for all non-technological Industry 4.0 requirements, with the highest for Open Resources (0.658). The degree of familiarity with these non-technological requirements of Industry 4.0 impacts the level of development of the technological potential of the SMART enterprise because it is necessary to create a technological platform that introduces essential elements such as operational efficiency and quality, intensive production methods and inter-organisational cooperation. The result is creating a SMART Factory based on the latest communication technologies adapted to the requirements and standards of the age of Industry 4.0.

Given the previously identified deficiencies in the enterprises' R&D spheres, this approach is an essential and justified support for the researched enterprises. In the age of Industry 4.0, organisations must systematically adapt to new requirements and standards based on the latest communication technologies and frameworks to create SMART Factories. Open Resources are a great support in this. Recognition and awareness of this fact can facilitate the building of technological potential for many, even smaller enterprises.

Table 4.38. Assessment of the relationship between SITP and the degree of familiarity with the non-technological requirements of Industry 4.0 in the surveyed enterprises

Non-technological requirements of Industry 4.0	Chi-square/ Fisher's statistics	df	Asymptotic/exact significance (2-sided)	Kendall's Tau-c coefficient	Exact significance (2-sided)
Open Resources	273.135*	88	0.001**	**0.658**	0.001**
Information Transparency	210.353	88	0.001**	0.582	0.001**
Interconnection	198.181	88	0.001**	0.577	0.001**
Open Knowledge	263.738	88	0.001**	0.571	0.001**
Open business models	228.701	88	0.001**	0.569	0.001**
Design Thinking	213.786	88	0.001**	0.568	0.001**
Open Culture	234.371	88	0.001**	0.556	0.001**
Decentralised Decisions	206.162	88	0.001**	0.551	0.001**
Technical Assistance	234.327	88	0.001**	0.511	0.001**
Desire for continuous development	173.124	88	0.001**	0.502	0.001**
Flexible and creative thinking	164.973	88	0.001**	0.497	0.001**
Ability to work in a team	179.218	88	0.001**	0.490	0.001**
Openness to new experiences	161.134	88	0.001**	0.487	0.001**
Ability to share knowledge	159.708	88	0.001**	0.434	0.001**
Ability to act quickly and make strategic decisions	186.371	88	0.001**	0.428	0.001**

* Unfulfilled assumption of the chi-square independence test, so that the expected counts in all cells of the contingency table are greater than or equal to 5.
** Statistically significant relationship (α = 0.001).

Source: own elaboration.

It was then examined whether there was a relationship between SIDFNTRI4.0[397], and SITP (see Figure 4.32).

The scatter plot analysis showed the relationship's linear characteristic, so Pearson's linear correlation coefficient was used to test it. The correlation turned out to be statistically significant ($p < 0.001$), positive and significant $r = 0.777$, i.e.**the higher the degree of familiarity with the non-technological requirements of Industry 4.0, the higher the level of development of the enterprise's technological potential**.

The results of the analyses carried out confirmed **H1: Degree of familiarity with the requirements of the age of Industry 4.0 supports the development of the technological potential of SMART enterprises.**

A further stage of the research was aimed at verifying hypothesis H2, that the application of solutions compliant with the requirements of the age of Industry 4.0 increases the development level of SMART enterprises' technological potential. To this

397 Broader described in subchapter 4.2.

end, the relationship between SITP and the scope to which Industry 4.0 technologies are applied in the enterprise was first examined (see Table 4.39).

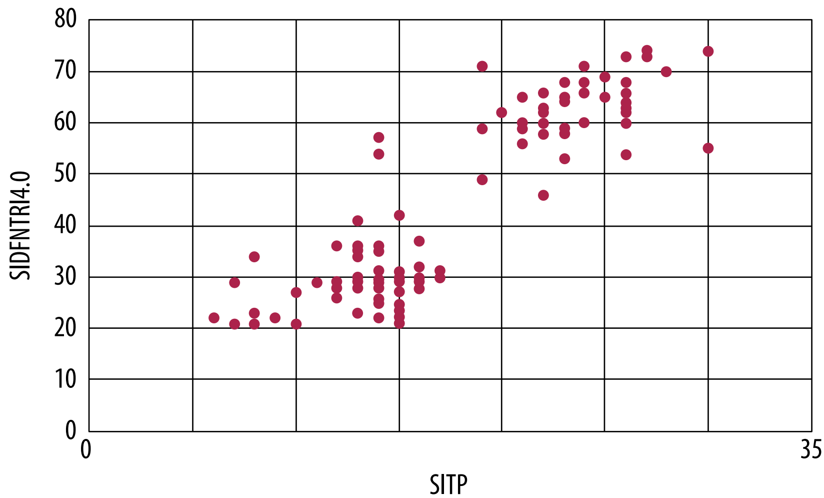

Figure 4.32. Scatter plot for variables SIDFNTRI4.0 and SITP

Source: own elaboration.

Table 4.39. Assessment of the relationship between SITP and the scope of application of Industry 4.0 technologies in the surveyed enterprises

Industry 4.0 technologies	Chi-square/ Fisher's statistics	df	Asymptotic/exact significance (2-sided)	Kendall's Tau-c coefficient	Exact significance (2-sided)
Robotisation	311.151*	88	0.001**	**0.606**	0.001**
Blockchain	390.706*	88	0.001**	**0.597**	0.001**
Information Network	285.118*	88	0.001**	**0.588**	0.001**
Mass Customisation	297.243*	88	0.001**	0.584	0.001**
Radio Frequency Identification	376.999*	88	0.001**	0.571	0.001**
Big Data Analytics	281.950*	88	0.001**	0.569	0.001**
Geolocalisation	276.960*	88	0.001**	0.569	0.001**
Cybersecurity	223.500*	88	0.001**	0.567	0.001**
M2M Communication	323.073*	88	0.001**	0.565	0.001**
Additive Manufacturing	273.466*	88	0.001**	0.565	0.001**
Cyber-Physical Systems	272.691*	88	0.001**	0.548	0.001**
Cloud Computing	252.720*	88	0.001**	0.517	0.001**
Digital Twin	273.207*	88	0.001**	0.338	0.001**
Virtual Reality, Augmented Reality	242.429*	66	0.001**	0.322	0.001**

Industry 4.0 technologies	Chi-square/ Fisher's statistics	df	Asymptotic/exact significance (2-sided)	Kendall's Tau-c coefficient	Exact significance (2-sided)
Artificial Intelligence	264.413*	88	0.001**	0.312	0.001**
Neural Networks	208.762*	66	0.001**	0.290	0.001**
Internet of Things, Internet of Services	186.876*	88	0.001**	0.158	0.016

* Unfulfilled assumption of the chi-square independence test, so that the expected counts in all cells of the contingency table are greater than or equal to 5.
** Statistically significant relationship ($\alpha = 0.001$).

Source: own elaboration.

The research results confirm a statistically significant relationship between the scope of application of Industry 4.0 technologies and the level of development of SMART enterprises' technological potential. The strength of the relationship, as measured by Kendall's tau-c coefficient, is moderate for 12 technologies and weak for five. However, it is worth pointing out three Industry 4.0 technologies for which the correlation with the level of development of the enterprise's technological potential proved to be the strongest, i.e., Robotisation (0.606), Blockchain (0.597) and Information Network (0.588). The application of these technologies has an impact on the level of development of the technological potential of a SMART enterprise, as they make it possible to increase the efficiency of production processes and to gather the necessary information to develop the ability to implement and adapt solutions of the age of Industry 4.0. They are used to an enormous scope to partially take over man's role while simultaneously leaving the possibility of cooperation in various spheres of production, business and public in a virtual space.

Continuing the analysis, it was examined whether there was a relationship between SISAI4.0T[398], and SITP (see Figure 4.33).

The scatter plot analysis showed the relationship's linear characteristic, so Pearson's linear correlation coefficient was used to test it. The correlation was statistically significant ($p < 0.001$), positive and significant $r = 0.820$, i.e. **the higher the scope of application of Industry 4.0 technologies, the higher the technological potential development level**.

398 Broader described in subchapter 4.2.

Figure 4.33. Scatter plot for the variables SISAI4.0T and SITP

Source: own elaboration.

The relationship between SITP and the scope of application of non-technological Industry 4.0 requirements in the enterprise was then examined (see Table 4.40).

Table 4.40. Assessment of the relationship between SITP and the scope of application of non-technological Industry 4.0 requirements in the surveyed enterprises

Non-technological requirements of Industry 4.0	Chi-square/ Fisher's statistics	df	Asymptotic/exact significance (2-sided)	Kendall's Tau-c coefficient	Exact significance (2-sided)
Information Transparency	226.264	88	0.001**	**0.551**	0.001**
Open Knowledge	270.314	88	0.001**	**0.551**	0.001**
Design Thinking	210.175	88	0.001**	**0.548**	0.001**
Interconnection	270.083	88	0.001**	**0.548**	0.001**
Technical Assistance	243.013	88	0.001**	0.535	0.001**
Open Culture	171.220	66	0.001**	0.504	0.001**
Flexible and creative thinking	152.211	66	0.001**	0.436	0.001**
Ability to work in a team	174.356	66	0.001**	0.429	0.001**
Decentralised Decisions	258.984	88	0.001**	0.426	0.001**
Desire for continuous development	158.206	66	0.001**	0.414	0.001**
Openness to new experiences	158.946	66	0.001**	0.397	0.001**
Open Resources	222.921*	88	0.001**	0.383	0.001**
Ability to share knowledge	147.404	66	0.001**	0.343	0.001**

Non-technological requirements of Industry 4.0	Chi-square/ Fisher's statistics	df	Asymptotic/exact significance (2-sided)	Kendall's Tau-c coefficient	Exact significance (2-sided)
Ability to act quickly and make strategic decisions	200.268	88	0.001**	0.311	0.001**
Open business models	163.631	88	0.001**	0.281	0.001**

* Unfulfilled assumption of the chi-square independence test, so that the expected counts in all cells of the contingency table are greater than or equal to 5.
** Statistically significant relationship (α = 0.001).

Source: own elaboration.

In this case, there is also a statistically significant relationship between the scope to which non-technological Industry 4.0 requirements are applied and the level of development of the enterprise's technological potential. The strength of the relationship, as measured by Kendall's coefficient

Kendall's tau-c is moderate for the 10 non-technological requirements of Industry 4.0 and highest for Open Knowledge (0.551), Information Transparency (0.551), Design Thinking (0.548) and Interconnection (0.548). The application of these non-technological requirements of Industry 4.0 has a significant impact on the level of development of the technological potential of the SMART enterprise because they identify with the communication of machines, sensors, and devices with people through the latest communication channels based on the Internet of Things (IoT) or Internet of People (IoP), the collection of results, the identification of critical areas, the widespread sharing of knowledge in technological, business and the economic areas. The result of these activities is the effective management of processes and the building of competitive strategies, which can be essential in achieving a competitive advantage in the age of Industry 4.0.

It was then examined whether there was a relationship between SISANTRI4.0[399], and SITP (see Figure 4.34).

The scatter plot analysis showed the relationship's linear characteristic, so Pearson's linear correlation coefficient was used to test it. The correlation turned out to be significant ($p < 0.001$), positive and significant $r = 0.745$, i.e. **the higher the scope of application of non-technological Industry 4.0 requirements, the higher the technological potential development level**.

The results of the analyses carried out confirmed **H2: Application of solutions compliant with the requirements of the age of Industry 4.0 increases the development level of SMART enterprises' technological potential**.

399 Broader described in subchapter 4.2.

The next step investigated the relationship between SITP and SILTA[400] achieved by the SMART enterprise in the age of Industry 4.0. The analysis started by preparing a scatter plot of the analysed variables (see Figure 4.35).

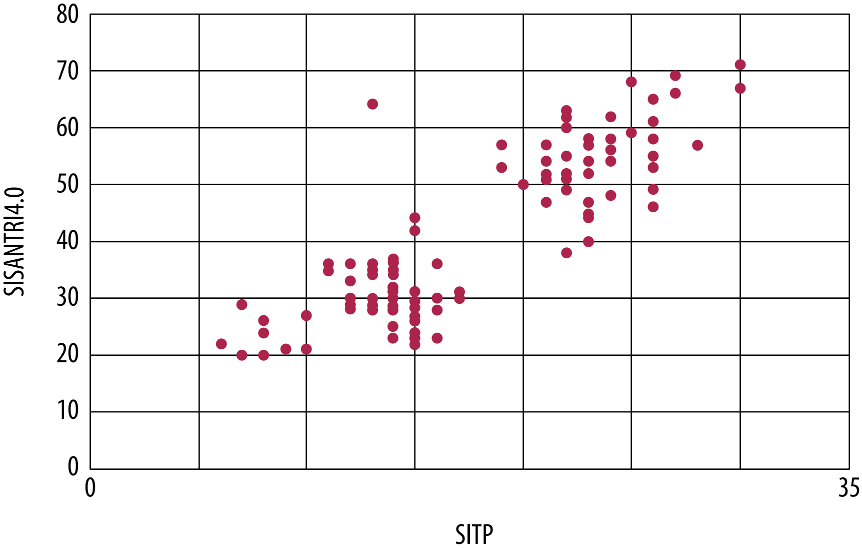

Figure 4.34. Scatter plot for the variables SISANTRI4.0 and SITP

Source: own elaboration.

Analysis of the scatter plot showed the linear characteristic of the relationship, so Pearson's linear correlation coefficient was used to test it. The correlation turned out to be statistically significant ($p < 0.001$), positive and significant $r = 0.830$, confirming the **H3: The higher the level of technological potential development, the higher the level of technological advantage obtained by SMART enterprises in the age of Industry 4.0**.

The aim of the next stage of the analysis was to examine the relationship between SILTA and the level of competitive advantage derived from the assessment of competitive factors (see Table 4.41).

400 It is the sum of the respondents' scores of the areas characterising technological advantage weighted according to the adopted rules for assessing the level of technological advantage described in detail in subchapter 2.4.

Figure 4.35. Scatter plot for the variables SITP and SILTA

Source: own elaboration.

Table 4.41. Assessment of the relationship between SILTA and the level of competitive advantage in the surveyed enterprises

Competitiveness factors	Chi-square/ Fisher's statistics	df	Asymptotic/exact significance(2-sid-ed)	Kendall's Tau-c coefficient	Exact significance (2-sided)
Technological innovations	121.457*	16	0.001**	**0.611**	0.001**
Knowledge and technological know-how	156.840*	16	0.001**	**0.576**	0.001**
Price of products/services	92.019*	12	0.001**	0.423	0.001**
Capacity for inter-organisational cooperation	85.786*	16	0.001**	0.398	0.001**
Financial capabilities	78.410*	12	0.001**	0.376	0.001**
Quality of products/services	74.041*	12	0.001**	0.357	0.001**
Customer relations	56.412*	8	0.001**	0.201	0.006
Attractive and differentiated offer	52.809*	12	0.001**	0.178	0.007
Corporate image	43.716*	12	0.001**	0.132	0.023
Competence of employees	31.674*	8	0.001**	0.048	0.503

* Unfulfilled assumption of the chi-square independence test, so that the expected counts in all cells of the contingency table are greater than or equal to 5.
** Statistically significant relationship (α = 0.001).

Source: own elaboration.

Analysis of the results showed statistically significant relationships between SILTA and the competitiveness factors – components of assessing the level of competitive advantage. The strength of the relationship, as measured by Kendall's tau-c coefficient, is moderate to weak and vital for Technological innovations (0.611) and Knowledge and technological know-how (0.576). It is because, in the age of Industry 4.0, technology development is one of the key factors relevant to the process of building competitive advantage, and expertise in technology and production processes enables the creation of technological innovations resulting from effective R&D activities.

It was then examined whether there was a relationship between SILTA and SILCA[401]. The analysis started by preparing a scatter plot of the analysed variables (see Figure 4.36).

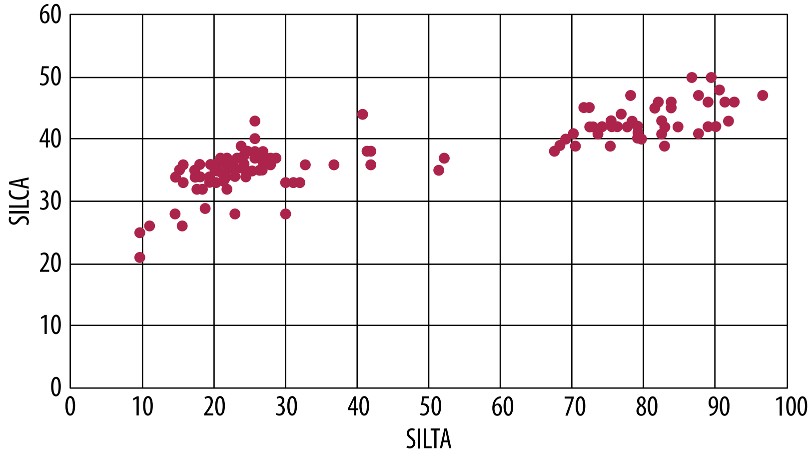

Figure 4.36. Scatter plot for SILTA and SILCA variables

Source: own elaboration.

The scatter plot analysis showed the relationship's linear characteristic, so Pearson's linear correlation coefficient was used to test it. The correlation was found to be statistically significant ($p < 0.001$), positive and significant $r = 0.731$, confirming the **H4: The higher the level of technological advantage, the higher the level of competitive advantage gained by SMART enterprises in the age of Industry 4.0**.

A summary of the results confirming the existence of correlations between the synthetic indicators is presented in Figure 4.37. Based on the obtained values of Pearson's linear correlation coefficient, it can be concluded that the strength of these correlations is significant, and the direction is positive. **The higher the level of technological advantage a given SMART enterprise has, the higher its competitive advantage.** It

401 Broader described in subchapter 4.2.

shows that the technological advantage of higher levels is an essential partial advantage affecting the final level of competitive advantage of a SMART enterprise in the age of Industry 4.0. Indeed, technological advantage is one of the key strategies for building a competitive advantage for SMART enterprises in the SMART world environment.

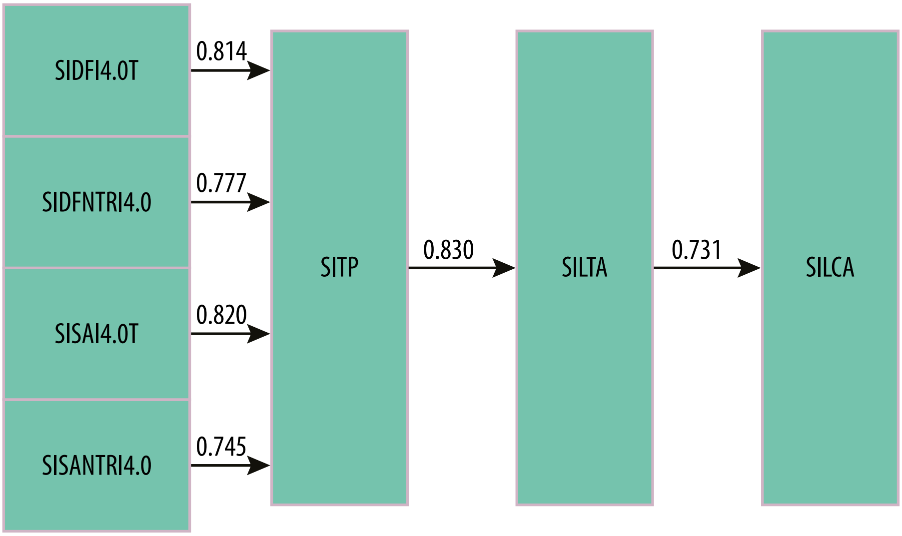

Figure 4.37. Results of research on the relationship between synthetic indicators
Source: own elaboration.

In the next step, the results of hypothesis testing were summarised (see Table 4.42), which shows that all specific hypotheses were positively verified so that the main hypothesis that **the ability to form a technological advantage in the age of Industry 4.0 increases the effectiveness of the process of building SMART enterprises' competitive advantage** can also be unambiguously confirmed.

The collected results of the statistical analyses gave rise to an attempt to develop a procedure to follow in the process of building a technological advantage in SMART enterprises. It is described in the following subchapter of this scientific monograph.

Table 4.42. Research hypotheses and the results of their empirical testing

Hypothesis	Results of hypothesis verification	Decision to accept or reject the hypothesis
H1: Degree of familiarity with the requirements of the age of Industry 4.0 supports the development of the technological potential of SMART enterprises.	Confirmed	Accepted

Hypothesis	Results of hypothesis verification	Decision to accept or reject the hypothesis
H2: Application of solutions compliant with the requirements of the age of Industry 4.0 increases the development level of SMART enterprises' technological potential.	Confirmed	Accepted
H3: The higher the level of technological potential development, the higher the level of technological advantage obtained by SMART enterprises in the age of Industry 4.0.	Confirmed	Accepted
H4: The higher the level of technological advantage, the higher the level of competitive advantage gained by SMART enterprises in the age of Industry 4.0.	Confirmed	Accepted

Source: own elaboration.

4.4. Procedure to follow in the process of building technological advantage

By analysing the results of the respondent's answers to the questions in the third section of the main part of the questionnaire according to the tool for assessing the level of technological advantage presented in subchapter 2.4, the current level of this advantage of the researched enterprises was determined. According to the classification used, this division had five levels. The analysis results showed that as many as 97 of 151 enterprises qualified for the group with the lowest levels of technological advantage (levels 1 and 2), and only 13 enterprises with the group having the highest fifth level of technological advantage (see Figure 4.38). The smallest representation was of entities classified in the third level of technological advantage, a transitional stage between basic and core technologies' scope of application. Considering the distribution of levels of technological advantage in the researched automotive production enterprises functionating in Poland, a significant number of entities conduct their activities only using basic technologies. It constitutes a significant limitation for them in building a competitive advantage based on the technological solutions applied.

The results of the conducted research are the basis for the conclusion that the tool proposed in subchapter 2.4 for assessing the level of technological advantage can be the foundation for constructing a procedure to follow in the process of building a technological advantage of a SMART enterprise. In this procedure, at individual levels, based on the respondents' assessments, key guidelines are proposed that allow for a detailed analysis of the current situation in terms of the technological advantage held and instructions for the enterprise aimed at improving this position.

The analysis began by comparing the required conditions for a given level of technological advantage (described in Table 2.15 in subchapter 2.4) with the respondents' answers (the number of points for the required conditions is in bold in the respective boxes of Tables 4.43–4.47). For this purpose, 20 enterprises were selected, i.e. four representing each level of technological advantage from the four most represented PKD subclasses in the research (29.32Z – Manufacture of other parts and accessories for motor vehicles excluding motorcycles, 28.15Z – Manufacture of bearings, gears, gearing and driving elements, 29.31Z – Manufacture of electrical and electronic equipment for motor vehicles, 22.11Z – Manufacture of rubber tyres and tubes; retreading and rebuilding of rubber tyres). When selecting enterprises, care was taken to represent entities with different points obtained, the highest or the lowest from given PKD subclasses, depending on the results obtained earlier in the research, at each analysed level of technological advantage to compare them.

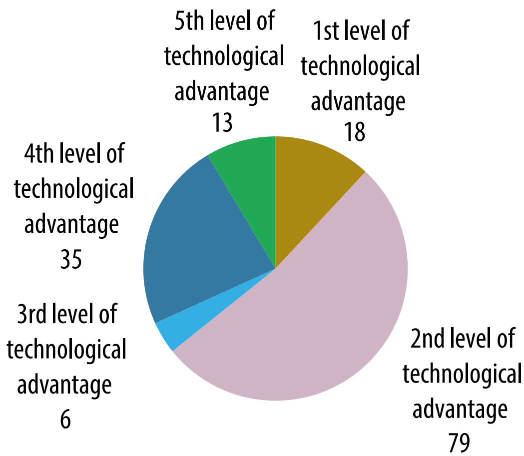

Figure 4.38. Structure of the research sample by the level of technological advantage
Source: own elaboration.

For the **first level of technological advantage** (see Table 4.43) in the **scoping** section, we found that the intensity of applying basic technologies was rated as low in all enterprises analysed at this level. It means that enterprises at this level have a feeble ability to build a technological advantage based on applied technologies due to their meagre potential and cannot benefit from these technologies as a basis for further activities to introduce and develop new technologies. Further analysis of the scoping area showed that cooperation with suppliers, customers and investors is low (cases 1.3, 1.4) or medium (cases 1.1, 1.2) important in creating new technologies. It shows that enterprises at this level refrain from using these types of relationships, which are most often sources of new ideas and solutions used to create new technologies that may impact building a competitive advantage in the future. The enterprises researched considered that knowing the technologies currently used by competitors has no (cases 1.1, 1.3) or low (cases 1.2, 1.4) importance in the process of creating new technologies. It may indicate a low level of technological intelligence necessary to compete in the age of Industry 4.0.

The analysis of the next **searching** section showed that in the researched enterprises, there is no (cases 1.1, 1.3) or low (cases 1.2, 1.4) importance of market analysis in terms of technologies available and usable in the process of searching for new technologies, which may indicate the lack of new knowledge that could be a source of opportunities for new technological solutions and the limited scope of their search. Furthermore, in this section, the other conditions identified in Table 2.15 as not required were rated as either not (case 1.1) or low importance (cases 1.2, 1.3, 1.4). The implication is that the enterprises researched fail to recognise and exploit the potential of internal and external sources for searching for new technologies. In practice, using these sources is significant for enterprises operating in the age of Industry 4.0 environment, as their competitiveness depends on their ability to respond to market needs, and new technologies, in particular, are helpful in this regard.

In turn, the analysis of the **evaluating** section leads to the conclusion that the enterprises surveyed needed to perceive the importance of assessing technological potential. It made it difficult for them to formulate an effective strategy and perceive their market situation. The main reason for this was a need for more knowledge of current technologies, which significantly limited the use of such skills. Also, the other conditions necessary in implementing new technologies had no (case 1.1) or low (cases 1.2, 1.3, 1.4) importance for the researched enterprises at this level of technological advantage.

Table 4.43. Distribution of points of enterprises having 1st level of technological advantage

List of conditions	Enterprises having 1st level of technological advantage			
	Cases			
	1.1	1.2	1.3	1.4
Scoping				
Possession of basic technologies	2	2	2	2
Possession of core technologies	–	–	–	–
Possession of emerging technologies	–	–	–	–
Conducting R&D activity	–	–	–	–
Development of R&D infrastructure	–	–	–	–
Investment in R&D activity	–	–	–	–
Development of R&D employees	–	–	–	–
Cooperation with external R&D centres, e.g. universities	–	–	–	–
Management competence to create new technologies	–	–	–	–
Management's willingness to bear the risks arising from the creation of new technologies	–	–	–	–

List of conditions	Enterprises having 1st level of technological advantage			
	Cases			
	1.1	1.2	1.3	1.4
Competence of R&D employees in the creation of new technology	–	–	–	–
Adequate level of the technological potential of the enterprise for the creation of new technologies	–	–	–	–
The financial capacity of the enterprise to create and develop new technologies	–	–	–	–
Knowledge of technologies currently used by competing enterprises	1	2	1	2
Cooperation with suppliers	**3**	**3**	**2**	**2**
Cooperation with customers	**3**	**3**	**2**	**2**
Cooperation with investors	**3**	**3**	**2**	**2**
Searching				
Management searches for sources of new technology within the enterprise	1	2	1	2
Search for external sources of new technology (e.g. analysis of public technology licences, analysis of technical and industry literature, analysis of patents and literature citations)	1	2	1	2
Market analysis for new technologies available for current use in the enterprise	**1**	**2**	**1**	**2**
Market analysis for new technologies available for future use in the enterprise	**1**	**2**	**1**	**2**
Establishment of cooperation with external originators of new technologies	1	2	2	2
Searching for new employees for the creation and implementation of new technologies	1	2	2	4
Monitoring the behaviour of competitors concerning the creation and implementation of new technologies	1	2	2	3
Evaluating				
Ability to assess technological potential from a market perspective	**1**	**2**	**2**	**2**
Analysis and assessment of technological potential from the point of view of the relationship with corporate strategy	**1**	**2**	**2**	**2**
Analysis and assessment of technological potential from the point of view of necessary investments	1	2	2	2
Analysis and assessment of technological potential from the point of view of the possibility of commercialisation of the technology	–	–	–	–
Analysis and assessment of technological potential from the point of view of the expected return on investment	1	1	2	2
Ability to assess the risk of implementing new technologies	1	2	2	2
Ability to assess the impact of technology on implemented product innovations and business processes	1	2	1	2
Committing				
Application of the watch and wait approach	–	–	–	–
Application of the position and learn approach	–	–	–	–
Application of the sense and follow approach	–	–	–	–
Application of the believe and lead approach	–	–	–	–

List of conditions	Enterprises having 1st level of technological advantage			
	Cases			
	1.1	1.2	1.3	1.4
Sum of points	11.2	16.4	13.2	16.8

Source: own elaboration.

The analysis of the **second level of technological advantage** (see Table 4.44) in the **scoping** section showed that the intensity of application of basic technologies was rated as low (cases 2.1, 2.3) or medium (cases 2.2, 2.4) in the enterprises analysed at this level. As in level one, enterprises cannot build a technological advantage based on applied technologies. Further analysis of the scoping area showed that cooperation with suppliers, customers and investors is of high (cases 2.1, 2.2) or very high (cases 2.3, 2.4) importance in the process of creating new technologies. It shows that enterprises at this level use such relationships as a source of new ideas and solutions to enable them to work towards new technologies in the future, which impacts building a competitive advantage. The enterprises researched considered that knowing the technologies currently used by competitors is essential in the process of creating new technologies. It means that they monitor its current level of technological development, and they perceive that these solutions can also influence the creation of their competitive advantage.

The analysis of the next **searching** section showed that in the researched enterprises, it is essential to analyse the market in terms of technologies available and possible to use in the process of searching for new technologies, which may indicate the desire to acquire new knowledge that could be a source of opportunities for new technological solutions. Furthermore, the search for sources of new technologies both within the enterprise (mobilisation of management for these activities) and externally through analysis of technical and industry literature and in the form of cooperation with external developers of such technologies is also of high importance. The search for new employees capable of creating and implementing new technologies is also significant, and it allows both the expansion of knowledge and the building of a research team capable of achieving new technological goals. If an enterprise can create new technologies, it is also essential for it to monitor competitors in this area. It makes it possible to review the available technologies and adapt new solutions to market needs avoiding duplication with competitors.

The analysis of the **evaluating** section allows the conclusion that the researched enterprises perceived the importance of assessing their technological potential from the point of view of their business strategy, market, necessary investments and expected return on investment. Also, other conditions, such as the ability to assess the risk of implementing new technologies and their impact on the product innovations and business processes required in implementing new technologies, were highly important to the researched enterprises.

Table 4.44. Distribution of points of enterprises having 2nd level of technological advantage

List of conditions	Enterprises having 2nd level of technological advantage – Cases			
	2.1	2.2	2.3	2.4
Scoping				
Possession of basic technologies	2	3	2	3
Possession of core technologies	–	–	–	–
Possession of emerging technologies	–	–	–	–
Conducting R&D activity	–	–	–	–
Development of R&D infrastructure	–	–	–	–
Investment in R&D activity	–	–	–	–
Development of R&D employees	–	–	–	–
Cooperation with external R&D centres, e.g. universities	–	–	–	–
Management competence to create new technologies	–	–	–	–
Management's willingness to bear the risks arising from the creation of new technologies	–	–	–	–
Competence of R&D employees in the creation of new technology	–	–	–	–
Adequate level of the technological potential of the enterprise for the creation of new technologies	–	–	–	–
The financial capacity of the enterprise to create and develop new technologies	–	–	–	–
Knowledge of technologies currently used by competing enterprises	4	4	4	4
Cooperation with suppliers	4	4	5	5
Cooperation with customers	4	4	5	5
Cooperation with investors	4	4	5	5
Searching				
Management searches for sources of new technology within the enterprise	4	4	3	4
Search for external sources of new technology (e.g. analysis of public technology licences, analysis of technical and industry literature, analysis of patents and literature citations)	4	4	3	4
Market analysis for new technologies available for current use in the enterprise	4	4	3	5
Market analysis for new technologies available for future use in the enterprise	4	4	3	5
Establishment of cooperation with external originators of new technologies	4	4	3	4
Searching for new employees for the creation and implementation of new technologies	4	4	3	5
Monitoring the behaviour of competitors concerning the creation and implementation of new technologies	4	4	3	5
Evaluating				

List of conditions	Enterprises having 2nd level of technological advantage			
	Cases			
	2.1	2.2	2.3	2.4
Ability to assess technological potential from a market perspective	3	4	3	5
Analysis and assessment of technological potential from the point of view of the relationship with corporate strategy	4	4	3	5
Analysis and assessment of technological potential from the point of view of necessary investments	4	4	3	4
Analysis and assessment of technological potential from the point of view of the possibility of commercialisation of the technology	–	–	–	–
Analysis and assessment of technological potential from the point of view of the expected return on investment	4	4	3	4
Ability to assess the risk of implementing new technologies	4	4	3	4
Ability to assess the impact of technology on implemented product innovations and business processes	4	4	3	4
Committing				
Application of the watch and wait approach	–	–	–	–
Application of the position and learn approach	–	–	–	–
Application of the sense and follow approach	–	–	–	–
Application of the believe and lead approach	–	–	–	–
Sum of points	**28.8**	**30.2**	**25.2**	**33.8**

Source: own elaboration.

The analysis of the **third level of technological advantage** (see Table 4.45) in the **scoping** section showed that the intensity of application of basic technologies in the researched enterprises was rated as medium (cases 3.1, 3.2, 3.3) or high (case 3.2). Because of this, enterprises can build a technological advantage based on applied technologies. At this level, the intensity of the application of core technologies is low (case 3.4) and medium (cases 3.1, 3.2, 3.3), which is individual to the enterprise, creating a current set of competitive technologies. The effect of the above was a low (cases 3.3, 3.4) and medium (cases 3.1, 3.2) intensity of occurrence of forms of R&D activity such as investments in R&D activity and cooperation with external R&D centres. The other forms of R&D activity were absent in the researched enterprises. According to the respondents, high (cases 3.3, 3.4) and very high (cases 3.1, 3.2) importance in the process of creating new technologies was attached to the willingness of the management to bear risks and their competence. With adequate staff knowledge, an enterprise can take the actions required to effectively and efficiently create and implement new technologies. Also of high (cases 3.2, 3.3, 3.4) and very high (case 3.1) importance was the level of technological potential, which is a determinant of the creation of technological innovations. It is also worth noting that of high (cases 3.3, 3.4) and very high (cases 3.1, 3.2) importance was the financial capacity to create and develop new technologies. As the level of technology advances, the costs associated with potential investments in this area increase, resulting in the generation of higher added value for the customer and, consequently, the enterprise. The competence of employees to create new technologies was of low importance because these enterprises do not carry out R&D activities but rely on finished results from other sources of R&D activities. The importance of the other required conditions from this section is similar or higher to the second level of technological advantage.

Regarding the **searching** and **evaluating** sections, the results show that these conditions' importance is similar or higher to the second level of technological advantage. In addition, in the evaluating section, the importance of analysing and evaluating technological potential from the point of view of the possibility of commercialising the technology was examined, which shows that this analysis is essential in the process of implementing new technologies, according to the respondents.

Furthermore, in the **committing** section, all approaches to technology implementation identified in Table 2.15 as not requiring 'watch and wait', 'position and learn', 'sense and follow', or 'believe and lead' were used to a low (cases 3.3, 3.4) or medium (cases 3.1, 3.2) scope. The effect of such low scores is that enterprises with the third level of technological advantage only meet some of the required conditions in the other sections, which does not allow for a higher intensity of application of approaches to technology implementation.

Table 4.45. Distribution of points of enterprises having 3rd level of technological advantage

List of conditions	Enterprises having 3rd level of technological advantage			
	Cases			
	3.1	3.2	3.3	3.4
Scoping				
Possession of basic technologies	**3**	**4**	**3**	**3**
Possession of core technologies	**3**	**3**	**3**	**2**
Possession of emerging technologies	–	–	–	–
Conducting R&D activity	1	1	1	1
Development of R&D infrastructure	1	1	1	1
Investment in R&D activity	**3**	**3**	**2**	**2**
Development of R&D employees	1	1	1	1
Cooperation with external R&D centres, e.g. universities	**3**	**3**	**2**	**2**
Management competence to create new technologies	**5**	**5**	**4**	**4**
Management's willingness to bear the risks arising from the creation of new technologies	**5**	**5**	**4**	**4**

List of conditions	Enterprises having 3rd level of technological advantage			
	Cases			
	3.1	3.2	3.3	3.4
Competence of R&D employees in the creation of new technology	2	2	2	2
Adequate level of the technological potential of the enterprise for the creation of new technologies	5	4	4	4
The financial capacity of the enterprise to create and develop new technologies	5	5	4	4
Knowledge of technologies currently used by competing enterprises	5	5	4	4
Cooperation with suppliers	4	5	4	4
Cooperation with customers	4	5	5	4
Cooperation with investors	5	5	4	4
Searching				
Management searches for sources of new technology within the enterprise	4	5	4	4
Search for external sources of new technology (e.g. analysis of public technology licences, analysis of technical and industry literature, analysis of patents and literature citations)	4	4	4	4
Market analysis for new technologies available for current use in the enterprise	4	5	4	4
Market analysis for new technologies available for future use in the enterprise	4	5	5	4
Establishment of cooperation with external originators of new technologies	4	5	5	4
Searching for new employees for the creation and implementation of new technologies	4	5	4	4
Monitoring the behaviour of competitors concerning the creation and implementation of new technologies	4	4	4	4
Evaluating				
Ability to assess technological potential from a market perspective	4	4	4	4
Analysis and assessment of technological potential from the point of view of the relationship with corporate strategy	4	5	5	4
Analysis and assessment of technological potential from the point of view of necessary investments	4	5	4	4
Analysis and assessment of technological potential from the point of view of the possibility of commercialisation of the technology	4	4	4	4
Analysis and assessment of technological potential from the point of view of the expected return on investment	4	5	4	4
Ability to assess the risk of implementing new technologies	5	5	4	4
Ability to assess the impact of technology on implemented product innovations and business processes	4	5	4	4
Committing				
Application of the watch and wait approach	3	3	2	2
Application of the position and learn approach	3	3	2	2
Application of the sense and follow approach	3	3	2	2
Application of the believe and lead approach	3	3	2	2

List of conditions	Enterprises having 3rd level of technological advantage			
	Cases			
	3.1	3.2	3.3	3.4
Sum of points	**58.4**	**63.4**	**54.4**	**50.8**

Source: own elaboration.

The analysis of the **fourth level of technological advantage** (see Table 4.46) in the **scoping** section showed that the intensity of applying basic technologies in the researched enterprises was assessed as high. Because of this, enterprises have a high capacity to build a technological advantage based on applied technologies. At this level, the researched enterprises also applied core technologies to a medium (cases 4.1, 4.4) and high (cases 4.2, 4.3) intensity to create and maintain a competitive advantage. In addition, to low intensity, the enterprises researched applied emerging technologies identified in the tool (see Table 2.15) as not required for this level but are the result of ongoing R&D activities. Next, the intensity of the occurrence of the required forms of R&D activity, such as the conduct of R&D activity, the development of infrastructure for it, the development of R&D employees and their competence in the creation of new technologies, were analysed according to the technological advantage assessment tool (see Table 2.15). Respondents indicated a medium (cases 4.1, 4.4), high (case 4.2) and very high (case 4.3) intensity of these forms of R&D activity. It shows that enterprises at this level of technological advantage have advanced R&D activities that enable the commercialisation of research results, transfer, production and implementation of new technologies that are one of the components of achieving competitive advantage. The importance of the other required conditions from this section is similar or higher to the third level of technological advantage.

Regarding the **searching** and **evaluating** sections, the results show that the importance of these conditions is similar or higher for the third level of technological advantage. On the other hand, considering the section **committing**, the researched enterprises in the medium (cases 4.1, 4.2, 4.4) and high (case 4.3) range applied the approaches used in the process of implementing new technologies because they meet the conditions required in all the other sections, which enables them to apply them intensively.

Table 4.46. Distribution of points of enterprises having 4th level of technological advantage

List of conditions	Enterprises having 4th level of technological advantage			
	Cases			
	4.1	4.2	4.3	4.4
Scoping				
Possession of basic technologies	4	4	4	4
Possession of core technologies	3	4	4	3
Possession of emerging technologies	2	2	2	2
Conducting R&D activity	3	4	5	3
Development of R&D infrastructure	3	4	5	3
Investment in R&D activity	3	4	5	3
Development of R&D employees	3	4	5	4
Cooperation with external R&D centres, e.g. universities	4	4	4	4
Management competence to create new technologies	4	4	4	4
Management's willingness to bear the risks arising from the creation of new technologies	5	5	5	4
Competence of R&D employees in the creation of new technology	4	5	5	4
Adequate level of the technological potential of the enterprise for the creation of new technologies	5	4	4	5
The financial capacity of the enterprise to create and develop new technologies	4	4	5	4
Knowledge of technologies currently used by competing enterprises	5	4	4	5
Cooperation with suppliers	4	5	5	4
Cooperation with customers	5	5	4	3
Cooperation with investors	4	5	4	4
Searching				
Management searches for sources of new technology within the enterprise	4	4	4	4
Search for external sources of new technology (e.g. analysis of public technology licences, analysis of technical and industry literature, analysis of patents and literature citations)	5	4	5	4
Market analysis for new technologies available for current use in the enterprise	5	5	5	4
Market analysis for new technologies available for future use in the enterprise	4	5	5	4
Establishment of cooperation with external originators of new technologies	5	4	5	4
Searching for new employees for the creation and implementation of new technologies	5	4	5	4
Monitoring the behaviour of competitors concerning the creation and implementation of new technologies	4	4	4	5
Evaluating				
Ability to assess technological potential from a market perspective	5	4	5	4
Analysis and assessment of technological potential from the point of view of the relationship with corporate strategy	4	4	4	4

List of conditions	Enterprises having 4th level of technological advantage			
	Cases			
	4.1	4.2	4.3	4.4
Analysis and assessment of technological potential from the point of view of necessary investments	5	4	5	5
Analysis and assessment of technological potential from the point of view of the possibility of commercialisation of the technology	4	5	4	5
Analysis and assessment of technological potential from the point of view of the expected return on investment	4	5	4	4
Ability to assess the risk of implementing new technologies	5	4	5	4
Ability to assess the impact of technology on implemented product innovations and business processes	4	4	5	4
Committing				
Application of the watch and wait approach	3	3	4	3
Application of the position and learn approach	3	4	4	3
Application of the sense and follow approach	3	3	4	3
Application of the believe and lead approach	3	3	4	3
Sum of points	72.4	76.6	81.8	70.2

Source: own elaboration.

Enterprises qualified for the **fifth level of technological advantage** (see Table 4.47) obtained the highest number of points in all analysed sections (4 and 5 points). It indicates that all the required conditions (according to the tool for assessing the level of technological advantage from subchapter 2.4) have been met for achieving the highest level of technological advantage. At this level, the intensity of the application of emerging technologies is high (cases 5.1, 5.2) and very high (cases 5.3, 5.4). It allows them to create and use pioneering, cutting-edge technologies that directly result from advanced R&D activities. Regarding the other required conditions from the **scoping** section, as well as **searching**, **evaluating** and **committing**, the results show that these conditions' importance is the highest in relation to the other levels of technological advantage.

Table 4.47. Distribution of points of enterprises having 5th level of technological advantage

List of conditions	Enterprises having 5th level of technological advantage			
	Cases			
	5.1	5.2	5.3	5.4
Scoping				
Possession of basic technologies	5	5	5	5
Possession of core technologies	5	5	5	5
Possession of emerging technologies	4	4	5	5
Conducting R&D activity	4	5	5	5
Development of R&D infrastructure	5	5	5	4
Investment in R&D activity	4	4	5	4
Development of R&D employees	5	4	5	5
Cooperation with external R&D centres, e.g. universities	4	4	4	5
Management competence to create new technologies	4	4	5	4
Management's willingness to bear the risks arising from the creation of new technologies	5	4	5	5
Competence of R&D employees in the creation of new technology	4	5	5	5
Adequate level of the technological potential of the enterprise for the creation of new technologies	4	4	5	5
The financial capacity of the enterprise to create and develop new technologies	5	4	5	5
Knowledge of technologies currently used by competing enterprises	5	4	5	5
Cooperation with suppliers	4	4	4	4
Cooperation with customers	5	4	5	4
Cooperation with investors	4	4	5	5
Searching				
Management searches for sources of new technology within the enterprise	5	5	5	4
Search for external sources of new technology (e.g. analysis of public technology licences, analysis of technical and industry literature, analysis of patents and literature citations)	4	5	4	4
Market analysis for new technologies available for current use in the enterprise	5	4	5	5
Market analysis for new technologies available for future use in the enterprise	4	4	5	5
Establishment of cooperation with external originators of new technologies	5	5	4	4
Searching for new employees for the creation and implementation of new technologies	5	4	5	4
Monitoring the behaviour of competitors concerning the creation and implementation of new technologies	4	5	5	5
Evaluating				
Ability to assess technological potential from a market perspective	5	4	5	5
Analysis and assessment of technological potential from the point of view of the relationship with corporate strategy	4	5	4	5

List of conditions	Enterprises having 5th level of technological advantage			
	Cases			
	5.1	5.2	5.3	5.4
Analysis and assessment of technological potential from the point of view of necessary investments	5	4	4	5
Analysis and assessment of technological potential from the point of view of the possibility of commercialisation of the technology	5	4	5	5
Analysis and assessment of technological potential from the point of view of the expected return on investment	5	4	5	5
Ability to assess the risk of implementing new technologies	5	4	5	4
Ability to assess the impact of technology on implemented product innovations and business processes	5	4	5	4
Committing				
Application of the watch and wait approach	4	4	4	4
Application of the position and learn approach	4	4	5	4
Application of the sense and follow approach	4	4	5	5
Application of the believe and lead approach	4	4	5	4
Sum of points	**89.8**	**86.8**	**97**	**94**

Source: own elaboration.

Analysing the results of the respondent's answers to the questions in the third section of the main part of the questionnaire, a procedure was prepared to follow in the process of building the technological advantage of the SMART enterprise. It allows the grouping of the technological advantage building conditions required for each level of technological advantage. The necessary conditions for each level of technological advantage were divided into sets in terms of their importance (the names of the sets are described in Table 4.48), which were prioritised accordingly.

Table 4.48. Names of the sets used in the procedure

Name	Description
1STLTA	1st level of technological advantage
2NDLTA	2nd level of technological advantage
3RDLTA	3rd level of technological advantage
4THLTA	4th level of technological advantage
5THLTA	5th level of technological advantage
RCP1	Required conditions with priority 1
RCP2	Required conditions with priority 2

Source: own elaboration.

1 STLTA (RCP1)
- Possession of basic technologies
- Cooperation with suppliers
- Cooperation with customers
- Cooperation with investors

1 STLTA (RCP2)
- Market analysis for new technologies available for current use in the enterprise
- Market analysis for new technologies available for future use in the enterprise
- Analysis and assessment of technological potential from the point of view of the relationship with corporate strategy
- Ability to assess technological potential from a market perspective

Reached 1st level of technological advantage

2NDLTA (RCP1)
- Searching for new employees for the creation and implementation of new technologies
- Knowledge of technologies currently used by competing enterprises
- Establishment of cooperation with external originators of new technologies
- Monitoring the behaviour of competitors concerning the creation and implementation of new technologies
- Ability to assess the impact of technology on implemented product innovations and business processes

2NDLTA (RCP2)
- Ability to assess the risk of implementing new technologies
- Analysis and assessment of technological potential from the point of view of necessary investments
- Analysis and assessment of technological potential from the point of view of the expected return on investment
- Search for external sources of new technology (e.g. analysis of public technology licences, analysis of technical and industry literature, analysis of patents and literature citations)
- Management searches for sources of new technology within enterprise

Reached 2nd level of technological advantage

3RDLTA (RCP1)
- Possession of core technologies
- Management's willingness to bear the risks arising from the creation of new technologies
- The financial capacity of the enterprise to create and develop new technologies
- Analysis and assessment of technological potential from the point of view of the possibility of commercialisation of the technology

3RDLTA (RCP2)
- Adequate level of the technological potential of the enterprise for the creation of new technologies
- Management competence to create new technologies
- Cooperation with external R&D centres, e.g. universities
- Investment in R&D activity

Reached 3rd level of technological advantage

4THLTA (RCP1)
- Competence of R&D employees in the creation of new technology
- Development of R&D employees
- Conducting R&D activity
- Development of R&D infastructure

4THLTA (RCP2)
- Application of the sense and follow approach
- Application of the believe and lead approach
- Application of the watch and wait approach
- Application of the position and learn approach

Reached 4th level of technological advantage

5THLTA (RCP1)
- Possession of emerging technologies

Reached 5th level of technological advantage

Figure 4.39. Procedure to follow in the process of building technological advantage in SMART enterprises

Source: own elaboration.

Once the level of technological advantage of an enterprise has been determined (this is done using the tool described in subchapter 2.4), it is positioned in a specific place in the procedure so that its current position in the process of building technological advantage can be known (see Figure 4.39). The correct use of the procedure requires the observance of two rules:

- The levels must not be skipped. They can only be achieved successively
- Only after fulfilling the conditions from the given sets for the respective level of technological advantage can one move on to the next one.

To achieve the first level of technological advantage, the conditions presented in two sets of prioritised conditions must be met. As priority 1, the enterprise must use basic technologies and cooperate with suppliers, customers and investors. In priority 2, the enterprise must do a market analysis for new technologies available for current and future use, analysis and assessment of technological potential from the point of view of the relationship with corporate strategy and have the ability to assess technological potential from a market perspective. Once the required conditions from both sets have been met, the enterprise can be considered to achieve the first level of technological advantage.

In order to achieve the second level of technological advantage, the conditions presented in two sets with assigned priorities must be met. As priority 1, the enterprise must search for new employees to create and implement new technologies, establish cooperation with external originators of new technologies and monitor competitors' behaviour concerning the creation and implementation of new technologies from the searching section. The enterprise should also know technologies currently used by competing enterprises from the scoping section and the ability to assess the impact of technology on implemented product innovations and business processes from the evaluating section. In priority 2, the enterprise must be able to assess the risk of implementing new technologies, carry out analysis and assessment of technological potential from the point of view of necessary investment and the expected return on investment from the evaluating section. The enterprise must also search for external sources of new technology and mobilise management to search the new technology sources within the enterprises from the searching section. Once the required conditions from both sets have been met, the enterprise can reach the second level of technological advantage.

To achieve the third level of technological advantage, the conditions presented in two separate prioritised sets must be met. As priority 1, the enterprise must use core technologies first. It is worth verifying management's willingness to bear the risks arising from the creation of new technologies and the financial capacity of the enterprise to create and develop new technologies. The enterprise must also carry out an analysis and assessment of technological potential from the point of view of the possibility of commercialisation of the technology. In priority 2, the enterprise must have an adequate level of technological potential of the enterprise for the creation of new technologies and introduce forms of R&D activity such as cooperation with external R&D centres and investment in R&D activity. It is also worth verifying the management's competence in creating new technologies. After fulfilling the required conditions from both sets, the enterprise can reach the third level of technological advantage. After fulfilling the required conditions from both sets, the enterprise achieves the third level of technological advantage.

In order to reach the fourth level of technological advantage, the conditions presented in two sets of priorities must be met. As priority 1, the enterprise must introduce forms of R&D activity such as competence of R&D employees in the creation of new technology, development of R&D employees, conducting R&D activity and development of R&D infrastructure. In priority 2, by fulfilling most of the conditions in the scoping section and all of the conditions in the searching and evaluating section, the enterprise is ready to use the approaches described in the committing section, such as 'sense and follow', 'believe and lead', 'watch and wait', 'position and learn' (description of approaches in Table 2.15). Once the required conditions from both sets have been met, the enterprise can be considered to have reached the fourth level of technological advantage.

Thus, to achieve the fifth level of technological advantage, one condition has to be met: the use of emerging technologies (description of emerging technologies in Table 2.15).

This condition is deliberately required last because it must fulfil all the requirements to apply this type of technology successfully. Once this condition is met, an enterprise can have the highest possible fifth level of technological advantage.

The procedure presented here is aimed at managers and people associated with the technological sphere in SMART production enterprises functionating in the age of Industry 4.0. It enables them to:
- to familiarise oneself with a structured list of requirements for building a technological advantage in the age of Industry 4.0,
- identify the current level of technological advantage,
- awareness of consecutive stages of action in the process of building technological advantage in the age of Industry 4.0,
- to prepare the enterprise for the next steps in the process of building a technological advantage,
- understanding the importance of technological advantage in the process of building a competitive advantage in the age of Industry 4.0 environment.

The main assumption of the procedure is to indicate the path the enterprise should follow to increase its technological advantage in the most advantageous, effective and efficient way to build a competitive advantage in the age of Industry 4.0 consciously.

Conclusions and Remarks

The scientific monograph considers the conditions for building a technological advantage of SMART enterprises in the age of Industry 4.0. In response to the noticed cognitive gaps, which resulted in a shortage of research on the analysis and evaluation of technological advantage of enterprises as conditions of building competitive advantage of SMART enterprises, in the scientific monograph, an attempt was made to complement the outlined research area, setting as the main objective of the scientific monographthe **identification and characterisation the conditions of technological advantage of SMART enterprises and to assess the dependence of the level of competitive advantage on the level of technological advantage of these enterprises**. This objective should be fulfilled in the course of the research proceedings. The above objective was decomposed into specific objectives, which were realised through a review of national and international literature and own research using the author's research tools (a questionnaire survey and a tool for assessing the level of technological advantage). In the course of the research carried out:

- the key requirements placed on SMART enterprises by the age of Industry 4.0 were identified,
- the conditions determining the building of a technological advantage in SMART enterprises were identified and systematised,
- a research tool was created to assess the level of technological advantage of SMART enterprises,
- examined the relationship between familiarity and application of the requirements of the age of Industry 4.0 and the level of the technological potential of SMART enterprises,
- the relationships between the level of development of technological potential and the level of technological advantage of SMART enterprises were examined,
- examined the relationship between the level of technological advantage and the level of competitive advantage of SMART enterprises,
- a procedure was developed to follow in the process of building technological advantage in SMART enterprises.

Based on the literature review, with the main and specific objectives of the study in mind, the main and specific hypotheses were formulated. The results of the empirical research made it possible to confirm all the formulated specific hypotheses (subchapter 4.3):

H1: Degree of familiarity with the requirements of the age of Industry 4.0 supports the development of the technological potential of SMART enterprises.

H2: Application of solutions compliant with the requirements of the age of Industry 4.0 increases the development level of SMART enterprises' technological potential.

H3: The higher the level of technological potential development, the higher the level of technological advantage obtained by SMART enterprises in the age of Industry 4.0.

H4: The higher the level of technological advantage, the higher the level of competitive advantage gained by SMART enterprises in the age of Industry 4.0.

Confirmation of the specific hypotheses allowed confirmation of the main hypothesis of the scientific monograph: **The ability to form a technological advantage in the age of Industry 4.0 increases the effectiveness of the process of building SMART enterprises' competitive advantage** (MH).

The result of this scientific monograph was the creation of a proprietary tool for determining an enterprise's current level of SMART technological advantage in the age of Industry 4.0 (see Appendix 2). The proposed tool consists of four stages:

- in the first one, based on the assessment of the intensity of application of technology (basic, core, emerging) in the enterprise in the last three years, one of the three sheets with the conditions of building technological advantage required for its levels are matched,
- in the second one, the appropriate sheet is filled in, providing answers on a scale from 1 to 5 (multiplying the results by the given weights makes it possible to determine the total number of points obtained),
- in the third one, the obtained result is compared with the score ranges appropriate for the given levels of technological advantage,
- in the fourth one, based on the procedure to follow in the process of technological advantage building, the enterprise's position is determined based on the defined current technological advantage, which shows what should be done to increase the current level of technological advantage by fulfilling the appropriate conditions specified in the procedure.

In conclusion, the theoretical considerations in the scientific monograph and the results of the research procedure fill the diagnosed cognitive gaps in the theoretical, empirical, methodical and practical dimensions. Because of this, its contribution to the development of management and quality sciences can be pointed out because, in the theoretical layer, knowledge was systematised in the field of defining the concepts of technological potential and technological advantage as components of building competitive advantage of an enterprise, conditions determining the construction of technological advantage in SMART enterprises were identified and an author's tool for assessing the current level of technological advantage of these enterprises was proposed. In the methodological context, the individual constructs in the research model were operationalised, and a methodology for measuring the level of technological advantage was proposed. In the empirical layer, quantitative research was carried out to examine the relationships between the constructs determining technological advantage and to develop a procedure to follow in the process of building technological advantage. In contrast, in the practical layer, conclusions were developed for business practice allowing for the improvement of the enterprise's competitiveness, especially those with SMART characteristics, through the appropriately targeted increase of their technological potential and building technological advantage.

The knowledge systematised in the scientific monograph on the conditions for building a technological advantage of SMART enterprises in the age of Industry 4.0, the proposed research model and the research tool can become a contribution to further research by both the author and other researchers. In turn, for practitioners, including representatives of enterprises, the developed tool for assessing the technological potential and the procedure for proceeding in the process of building the technological advantage of a SMART enterprise in the age of Industry 4.0 can support decision-making in building the technological potential of the enterprise by the technological and non-technological requirements of the age of Industry 4.0.

However, despite the great importance of the research carried out, especially in the context of developing the author's procedure aimed at supporting the process of building technological advantage in SMART enterprises, the author did not manage to avoid certain limitations, which include territorial scope, as the research was carried out only in Poland, only in production enterprises from the automotive industry. Therefore, it seems reasonable to extend the research to countries with higher experience in implementing the technological and non-technological requirements of the age of Industry 4.0 and to enterprises from other industries.

The method adopted, i.e. only quantitative research, which did not allow a more profound recognition of the causal relationships between technological advantage and competitive advantage, should also be pointed out as a limitation. Therefore, it is recommended that other qualitative methods are also used in future research.

Another limitation is the subjective list of factors defined based on current knowledge from the literature, which describes the level of development of technological potential and the level of technological advantage of SMART enterprises. Its periodic review and supplementation would strengthen the validity and usefulness of the tool proposed in the scientific monograph to assess the level of technological advantage of this group of enterprises.

A separate treatment is also required to identify and classify technological and non-technological requirements of the age of Industry 4.0 in the context of implications for assessing enterprises' technological advantage levels. It would also be interesting to conduct research relating to different periods to compare changes in the implementation strategies of technological and non-technological requirements of the age of Industry 4.0 and the effects of their implementation on the development of the technological potential of SMART enterprises. Empirical verification of these issues can become a source of new knowledge for entrepreneurs, increasing enterprise management's effectiveness in the age of Industry 4.0 environment.

The author of the scientific monograph is aware that the proposed directions of further research only exhaust some possibilities and hopes that undertaking them will allow for a complete recognition and understanding of the essence of building technological advantage as a component of competitive advantage.

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Appendix 1

Survey questionnaire

SECTION 1. ENTERPRISE CHARACTERISTICS (METRICS)

1. Please determine the number of years Your enterprise has been in business (select one and mark an X):

	up to 1 year
	between 1 and 5 years
	over 5 years to 10 years
	over 10 years to 15 years
	over 15 years

2. Please determine the average level of full-time equivalent employment in Your enterprise in the last year (select one and mark an X):

	10–49 persons
	50–249 persons
	over 249 persons

3. Please determine the type of activity of Your enterprise by PKD subclass (mark an X):

	Manufacture of rubber tyres and tubes; retreading and rebuilding of rubber tyres (22.11.Z)
	Manufacture of electric motors, generators and transformers (27.11.Z)
	Manufacture of batteries and accumulators (27.20.Z)
	Manufacture of bearings, gears, gearing and driving elements (28.15.Z)
	Manufacture of engines for motor vehicles (excluding motorcycles) and for agricultural tractors (29.10.A)
	Manufacture of cars (29.10.B)
	Manufacture of buses (29.10.C)
	Manufacture of motor vehicles for the transport of goods (29.10.D)
	Manufacture of other motor vehicles excluding motorcycles (29.10.E)
	Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers (29.20.Z)
	Manufacture of electrical and electronic equipment for motor vehicles (29.31.Z)
	Manufacture of other parts and accessories for motor vehicles excluding motorcycles (29.32.Z)
	Manufacture of military fighting vehicles (30.40.Z)
	Manufacture of motorcycles (30.91.Z)

4. Please determine Your enterprise's dominant market area (select one and mark an X):

	local
	regional
	national
	international
	global

SECTION 2. SMART ENTERPRISE FAMILIARITY AND APPLICATION OF INDUSTRY 4.0 REQUIREMENTS

5. Please rate **the degree of familiarity with the following technologies resulting from Industry 4.0 requirements** in Your enterprise (rating on a scale of 1 to 5, where 1 – No familiarity, 2 – Small familiarity, 3 – Medium familiarity, 4 – High familiarity, 5 – Very high familiarity)

Industry 4.0 technologies	Degree of familiarity				
	None	Small	Medium	High	Very high
	1	2	3	4	5
Internet of Things, Internet of Services					
Cyber-Physical Systems					
Information Network					
Cloud Computing					
Big Data Analytics					
M2M Communication					
Virtual Reality, Augmented Reality					
Cybersecurity					
Neural Networks					
Digital Twin					
Artificial Intelligence					
Blockchain					
Radio Frequency Identification					
Geolocalisation					
Additive Manufacturing					
Robotisation					
Mass Customisation					

6. Please rate **the degree of familiarity with the following non-technological requirements of Industry 4.0** in Your enterprise (rating on a scale of 1 to 5, where 1 – No familiarity, 2 – Small familiarity, 3 – Medium familiarity, 4 – High familiarity, 5 – Very high familiarity)

Non-technological requirements of Industry 4.0	Degree of familiarity				
	None	Small	Medium	High	Very high
	1	2	3	4	5
Open Resources					
Open Knowledge					
Open Culture					
Interconnection					
Decentralised Decisions					
Information Transparency					
Technical Assistance					
Design Thinking					
Open business models					
Ability to act quickly and make strategic decisions					
Ability to work in a team					
Ability to share knowledge					
Desire for continuous development					
Flexible and creative thinking					
Openness to new experiences					

7. Please rate **the scope to which the following technologies resulting from Industry 4.0 requirements** have been applied in Your enterprise (rating on a scale of 1 to 5, where 1 – Did not apply, 2 –Applied to a small scope, 3 – Applied to a medium scope, 4 – Applied to a large scope, 5 – Applied to a very large scope)

Industry 4.0 technologies	Scope of application				
	None	Small	Medium	Large	Very large
	1	2	3	4	5
Internet of Things, Internet of Services					
Cyber-Physical Systems					
Information Network					
Cloud Computing					
Big Data Analytics					
M2M Communication					
Virtual Reality, Augmented Reality					

Industry 4.0 technologies	Scope of application				
	None	Small	Medium	Large	Very large
	1	2	3	4	5
Cybersecurity					
Neural Networks					
Digital Twin					
Artificial Intelligence					
Blockchain					
Radio Frequency Identification					
Geolocalisation					
Additive Manufacturing					
Robotisation					
Mass Customisation					

8. Please rate **the scope to which the following non-technological requirements of Industry 4.0** have been applied in Your enterprise (rating on a scale of 1 to 5, where 1 – Did not apply, 2 –Applied to a small scope, 3 – Applied to a medium scope, 4 – Applied to a large scope, 5 – Applied to a very large scope)

Non-technological requirements of Industry 4.0	Scope of application				
	None	Small	Medium	Large	Very large
	1	2	3	4	5
Open Resources					
Open Knowledge					
Open Culture					
Interconnection					
Decentralised Decisions					
Information Transparency					
Technical Assistance					
Design Thinking					
Open business models					
Ability to act quickly and make strategic decisions					
Ability to work in a team					
Ability to share knowledge					
Desire for continuous development					
Flexible and creative thinking					
Openness to new experiences					

SECTION 3. TECHNOLOGICAL POTENTIAL OF SMART ENTERPRISE

9. Please rate Your enterprise's **technological potential developmen**t in the following areas (rating on a scale of 1 to 5, where 1 – Very Low, 2 – Low, 3 –Medium, 4 – High, 5 – Very high)

Areas	The level of technological potential development				
	Very low	Low	Medium	High	Very high
	1	2	3	4	5
Technology portfolio					
Intangible assets, including know-how					
Effectiveness of R&D activities					
Technological entrepreneurship					
Intellectual potential of employees					
Competitiveness of available technologies					

SECTION 4. ASSESSMENT OF THE LEVEL OF TECHNOLOGICAL ADVANTAGE OF SMART ENTERPRISE

10. Please rate **the intensity of application of the following technologies** in Your enterprise in the last three years (2019–2021) (rating on a scale of 1 to 5, where 1 – None, 2 – Low intensity, 3 – Medium intensity, 4 – High intensity, 5 – Very high intensity)

Technology types	Intensity of application				
	None	Low	Medium	High	Very high
	1	2	3	4	5
Basic Technologies – technologies available on the market enable the enterprise to function, and they are the basis for other activities toward technology development and implementation. They also refer to freely available technologies that can be purchased.					

Technology types	Intensity of application				
	None	Low	Medium	High	Very high
	1	2	3	4	5
Core Technologies – technologies that are more individual for a given enterprise as they form the current set of competitive technologies. These technologies can be sold to other enterprises after a certain period of use as a finished product.					
Emerging Technologies – pioneering, innovative technologies that are not available on the market are created due to the R&D activity of a given company. Very high costs and uncertainty characterise their regard to use.					

11. Please rate the **intensity of occurrence of various forms of R&D activity in your enterprise** in the last three years (2019–2021) (rating on a scale of 1 to 5, where 1 – None, 2 – Low intensity, 3 – Medium intensity, 4 – High intensity, 5 – Very high intensity)

Forms of R&D activity	Intensity of occurrence				
	None	Low	Medium	High	Very high
	1	2	3	4	5
Conducting R&D activities					
Development of R&D infrastructure					
Investment in R&D activity					
Development of R&D employees					
Cooperation with external R&D centres e.g. universities					

12. Please rate **the importance of the various conditions relevant to Your enterprise's new technology <u>development</u> process** in the last three years (2019–2021) (rating on a scale of 1 to 5, where 1 – No importance, 2 – Low importance, 3 – Medium importance, 4 – High importance, 5 – Very high importance)

Conditions	Importance				
	None	Low	Medium	High	Very high
	1	2	3	4	5
Management competence to create new technologies					
Management's willingness to bear the risks arising from the creation of new technologies					
Competence of R&D employees in the creation of new technology					
Level of the technological potential of the enterprise for the creation of new technologies					
The financial capacity of the enterprise to create and develop new technologies					
Knowledge of technologies currently used by competing enterprises					
Cooperation with suppliers					
Cooperation with customers					
Cooperation with investors					

13. Please rate **the importance of the various conditions relevant to Your enterprise's process of <u>finding</u> new technologies** in the last three years (2019–2021) (rating on a scale of 1 to 5, where 1 – No importance, 2 – Low importance, 3 – Medium importance, 4 – High importance, 5 – Very high importance)

Conditions	Importance				
	None	Low	Medium	High	Very high
	1	2	3	4	5
Management searches for sources of new technology within the enterprise					
Search for external sources of new technology (e.g. analysis of public technology licences, analysis of technical and industry literature, analysis of patents and literature citations)					
Market analysis for new technologies available for current use in the enterprise					

Conditions	Importance				
	None	Low	Medium	High	Very high
	1	2	3	4	5
Market analysis for new technologies available for future use in the enterprise					
Establishment of cooperation with external originators of new technologies					
Searching for new employees for the creation and implementation of new technologies					
Monitoring the behaviour of competitors concerning the creation and implementation of new technologies					

14. Please rate **the importance of the various conditions relevant to <u>implementing</u> new technologies** in Your enterprise in the last three years (2019–2021) (rating on a scale of 1 to 5, where 1 – No importance, 2 – Low importance, 3 – Medium importance, 4 – High importance, 5 – Very high importance)

Conditions	Importance				
	None	Low	Medium	High	Very high
	1	2	3	4	5
Ability to assess technological potential from a market perspective					
Analysis and assessment of technological potential from the point of view of the relationship with corporate strategy					
Analysis and assessment of technological potential from the point of view of necessary investments					
Analysis and assessment of technological potential from the point of view of the possibility of commercialisation of the technology					

Conditions	Importance				
	None	Low	Medium	High	Very high
	1	2	3	4	5
Analysis and assessment of technological potential from the point of view of the expected return on investment					
Ability to assess the risk of implementing new technologies					
Ability to assess the impact of technology on implemented product innovations and business processes					

15. Please rate **the intensity of application of the following <u>approaches</u> to technology implementation** in Your enterprise in the last three years (2019–2021) (rating on a scale of 1 to 5, where 1 – None, 2 – Low intensity, 3 – Medium intensity, 4 – High intensity, 5 – Very high intensity)

Approaches	Intensity of application				
	None	Low	Medium	High	Very high
	1	2	3	4	5
A 'watch and wait' approach is applied when a new technology's uncertainty is too great to start research and development. The company waits for developments and creates competitive barriers.					
A 'position and learn' approach is applied when the uncertainty associated with the new technology is low, allowing it to develop and stop the threat of competition. The company engages with the new technology creating a more active learning process.					

Approaches	Intensity of application				
	None	Low	Medium	High	Very high
	1	2	3	4	5
A 'sense and follow' approach is applied when a company completes identifying and evaluating a technology by deciding to invest in new technology. The company has a good chance of becoming a market leader while continuing an active commercialisation strategy.					
The 'believe and lead' approach is used when the capabilities of new technology are very promising, and an enterprise can fully commit its resources to the commercialisation of emerging technology. The enterprise makes a decision based on the intuition and experience of technology leaders in cutting-edge technology.					

SECTION 5. THE LEVEL OF COMPETITIVE ADVANTAGE OF SMART ENTERPRISE

16. Please rate Your enterprise's **level of competitive advantage with reference to the following competitiveness factors** (rating on a scale of 1 to 5, where 1 – Very low, 2 – Low, 3 –Medium, 4 – High, 5 – Very high)

Competitiveness factors	Level of competitive advantage				
	Very low	Low	Medium	High	Very high
	1	2	3	4	5
Competence of employees					
Knowledge and technological know-how					
Technological innovations					
Capacity for inter-organisational cooperation					
Customer relations					
Attractive and differentiated offer					
Corporate image					
Financial capabilities					
Price of products/services					

Competitiveness factors	Level of competitive advantage				
	Very low	Low	Medium	High	Very high
	1	2	3	4	5
Quality of products/services					

17. Please rate **the current competitive position** of Your enterprise (rating on a scale of 1 to 5, where 1 – Very low, 2 – Low, 3 – Medium, 4 – High, 5 – Very high)

Meters of competitive position	The level of meter				
	Very low	Low	Medium	High	Very high
	1	2	3	4	5
Share in sales					
Sales dynamics					
Profitability					
Return on investment					

18. How have **the following meters of Your enterprise's competitive position changed** in the last three years (2019–2021)

Meters of competitive position	Growth (by how many %)	Decrease (by how many %)
Share in sales		
Sales dynamics		
Profitability		
Return on investment		

Appendix 2

A tool for determining a SMART enterprise's current level of technological advantage in the age of Industry 4.0

The tool presented makes it possible to assess the level of a SMART enterprise's current level of technological advantage in the age of Industry 4.0 and position it in the right place in the process of building a technological advantage. It consists of four stages:
- in the first, based on an assessment of the intensity of technology use (basic, core, emerging) in the enterprise in the last three years, one of the three sheets from the technological advantage building conditions required for each level of technological advantage is matched,
- in the second one, the appropriate sheet is filled in, providing answers on a scale from 1 to 5 (multiplying the results by the given weights makes it possible to determine the total number of points obtained),
- in the third one, the obtained result is compared with the score ranges appropriate for the given levels of technological advantage,
- fourth, based on the procedure for building a technological advantage, the situation of the enterprise in terms of the current technological advantage is determined, and recommendations are made as to what should be done to increase the current level of technological advantage.

1. Rate the intensity of application of the following technologies in Your enterprise in the last three years (2019–2021) (rating on a scale of 1 to 5, where 1 – None, 2 – Low intensity, 3 – Medium intensity, 4 – High intensity, 5 – Very high intensity) by entering the appropriate number of points in Table 1.

Tabela 1. Assessment of the intensity of technology use in your enterprise over the last three years

Technology types	Intensity of application (1–5)
Basic Technologies – technologies available on the market enable the enterprise to function, and they are the basis for other activities toward technology development and implementation. They also refer to freely available technologies that can be purchased.	
Core Technologies – technologies that are more individual for a given enterprise as they form the current set of competitive technologies. These technologies can be sold to other enterprises after a certain period of use as a finished product.	

Technology types	Intensity of application (1–5)
Emerging Technologies – pioneering, innovative technologies that are not available on the market are created due to the R&D activity of a given company. Very high costs and uncertainty characterise their regard to use.	

2. Select the appropriate sheet to be filled in according to the guidelines below:
- if no core technologies are applied (value entered in Table 1) omit the value in the emerging technologies field and complete sheet 1,
- if no emerging technologies are applied (value entered in Table 1) complete sheet 2,
- if all types of technologies are applied fill in sheet 3.

Sheet 1			
List of conditions	**Number of points (1–5)**	**Weight**	**(Number of points) (Weight)**
Enter the values from Table 1 in the appropriate boxes to assess the intensity of application of the following technologies, which confirms its possession			
Possession of basic technologies		1	
Rate the importance of the various conditions relevant to Your enterprise's new technology development process in the last three years (2019–2021) (rating on a scale of 1 to 5, where 1 – No importance, 2 – Low importance, 3 – Medium importance, 4 – High importance, 5 – Very high importance)			
Knowledge of technologies currently used by competing enterprises		0.4	
Cooperation with suppliers		0.4	
Cooperation with customers		0.4	
Cooperation with investors		0.4	
Rate the importance of the various conditions relevant to Your enterprise's process of finding new technologies in the last three years (2019–2021) (rating on a scale of 1 to 5, where 1 – No importance, 2 – Low importance, 3 – Medium importance, 4 – High importance, 5 – Very high importance)			
Management searches for sources of new technology within the enterprise		0.4	
Search for external sources of new technology (e.g. analysis of public technology licences, analysis of technical and industry literature, analysis of patents and literature citations)		0.4	
Market analysis for new technologies available for current use in the enterprise		0.4	
Market analysis for new technologies available for future use in the enterprise		0.4	
Establishment of cooperation with external originators of new technologies		0.4	
Searching for new employees for the creation and implementation of new technologies		0.4	
Monitoring the behaviour of competitors concerning the creation and implementation of new technologies		0.4	

Sheet 1			
List of conditions	Number of points (1–5)	Weight	(Number of points) (Weight)
Rate the importance of the various conditions relevant to implementing new technologies in Your enterprise in the last three years (2019–2021) (rating on a scale of 1 to 5, where 1 – No importance, 2 – Low importance, 3 – Medium importance, 4 – High importance, 5 – Very high importance)			
Ability to assess technological potential from a market perspective		0.4	
Analysis and assessment of technological potential from the point of view of the relationship with corporate strategy		0.4	
Analysis and assessment of technological potential from the point of view of necessary investments		0.4	
Analysis and assessment of technological potential from the point of view of the expected return on investment		0.4	
Ability to assess the risk of implementing new technologies		0.4	
Ability to assess the impact of technology on implemented product innovations and business processes		0.4	
Total number of points			

Sheet 2			
List of conditions	Number of points (1–5)	Weight	(Number of points) (Weight)
Enter the values from Table 1 in the appropriate boxes to assess the intensity of application of the following technologies, which confirms its possession			
Possession of basic technologies		1	
Possession of core technologies		2	
Rate the intensity of occurrence of various forms of R&D activity in your enterprise in the last three years (2019–2021) (rating on a scale of 1 to 5, where 1 – None, 2 – Low intensity, 3 – Medium intensity, 4 – High intensity, 5 – Very high intensity)			
Conducting R&D activity		0.6	
Development of R&D infrastructure		0.6	
Investment in R&D activity		0.6	
Development of R&D employees		0.6	
Cooperation with external R&D centres, e.g. universities		0.6	
Rate the importance of the various conditions relevant to Your enterprise's new technology development process in the last three years (2019–2021) (rating on a scale of 1 to 5, where 1 – No importance, 2 – Low importance, 3 – Medium importance, 4 – High importance, 5 – Very high importance)			
Management competence to create new technologies		0.4	
Management's willingness to bear the risks arising from the creation of new technologies		0.4	

Sheet 2			
List of conditions	Number of points (1–5)	Weight	(Number of points) (Weight)
Competence of R&D employees in the creation of new technology		0.6	
Adequate level of the technological potential of the enterprise for the creation of new technologies		0.4	
The financial capacity of the enterprise to create and develop new technologies		0.4	
Knowledge of technologies currently used by competing enterprises		0.4	
Cooperation with suppliers		0.4	
Cooperation with customers		0.4	
Cooperation with investors		0.4	
Rate the importance of the various conditions relevant to Your enterprise's process of finding new technologies in the last three years (2019–2021) (rating on a scale of 1 to 5, where 1 – No importance, 2 – Low importance, 3 – Medium importance, 4 – High importance, 5 – Very high importance)			
Management searches for sources of new technology within the enterprise		0.4	
Search for external sources of new technology (e.g. analysis of public technology licences, analysis of technical and industry literature, analysis of patents and literature citations)		0.4	
Market analysis for new technologies available for current use in the enterprise		0.4	
Market analysis for new technologies available for future use in the enterprise		0.4	
Establishment of cooperation with external originators of new technologies		0.4	
Searching for new employees for the creation and implementation of new technologies		0.4	
Monitoring the behaviour of competitors concerning the creation and implementation of new technologies		0.4	
Rate the importance of the various conditions relevant to implementing new technologies in Your enterprise in the last three years (2019 –2021) (rating on a scale of 1 to 5, where 1 – No importance, 2 – Low importance, 3 – Medium importance, 4 – High importance, 5 – Very high importance)			
Ability to assess technological potential from a market perspective		0.4	
Analysis and assessment of technological potential from the point of view of the relationship with corporate strategy		0.4	
Analysis and assessment of technological potential from the point of view of necessary investments		0.4	
Analysis and assessment of technological potential from the point of view of the possibility of commercialisation of the technology		0.4	
Analysis and assessment of technological potential from the point of view of the expected return on investment		0.4	
Ability to assess the risk of implementing new technologies		0.4	
Ability to assess the impact of technology on implemented product innovations and business processes		0.4	

Sheet 2			
List of conditions	**Number of points (1–5)**	**Weight**	**(Number of points) (Weight)**
Rate the intensity of application of the following approaches to technology implementation in Your enterprise in the last three years (2019–2021) (rating on a scale of 1 to 5, where 1 – None, 2 – Low intensity, 3 – Medium intensity, 4 – High intensity, 5 – Very high intensity)			
Application of the **'watch and wait' approach** – used when a new technology's uncertainty is too great to start researching and developing it. The enterprise waits for developments and creates competitive barriers.		0.4	
Application of the **'position and learn' approach** – used when the uncertainty associated with new technology is low, allowing it to develop and stop the threat from competitors. The enterprise engages with the new technology creating a more active learning process.		0.4	
Application of the **'sense and follow' approach** – used when an enterprise completes the process of identifying and evaluating a technology by deciding to invest in new technology. The enterprise has a good chance of becoming a market leader while pursuing an active commercialisation strategy.		0.4	
Application of the **'believe and lead' approach** – used when new technology opportunities are auspicious, and an enterprise can fully commit its resources to commercialise the emerging technology. The enterprise makes a decision based on the intuition and experience of technology leaders at the cutting edge of technology.		0.4	
Total number of points			

Sheet 3			
List of conditions	**Number of points (1–5)**	**Weight**	**(Number of points) (Weight)**
Enter the values from Table 1 in the appropriate boxes to assess the intensity of application of the following technologies, which confirms its possession			
Possession of basic technologies		1	
Possession of core technologies		2	
Possession of emerging technologies		3	
Rate the intensity of occurrence of various forms of R&D activity in your enterprise in the last three years (2019–2021) (rating on a scale of 1 to 5, where 1 – None, 2 – Low intensity, 3 – Medium intensity, 4 – High intensity, 5 – Very high intensity)			
Conducting R&D activity		0.6	
Development of R&D infrastructure		0.6	
Investment in R&D activity		0.6	
Development of R&D employees		0.6	
Cooperation with external R&D centres, e.g. universities		0.6	

Sheet 3			
List of conditions	Number of points (1–5)	Weight	(Number of points) (Weight)
Rate the importance of the various conditions relevant to Your enterprise's new technology development process in the last three years (2019–2021) (rating on a scale of 1 to 5, where 1 – No importance, 2 – Low importance, 3 – Medium importance, 4 – High importance, 5 – Very high importance)			
Management competence to create new technologies		0.4	
Management's willingness to bear the risks arising from the creation of new technologies		0.4	
Competence of R&D employees in the creation of new technology		0.6	
Adequate level of the technological potential of the enterprise for the creation of new technologies		0.4	
The financial capacity of the enterprise to create and develop new technologies		0.4	
Knowledge of technologies currently used by competing enterprises		0.4	
Cooperation with suppliers		0.4	
Cooperation with customers		0.4	
Cooperation with investors		0.4	
Rate the importance of the various conditions relevant to Your enterprise's process of finding new technologies in the last three years (2019–2021) (rating on a scale of 1 to 5, where 1 – No importance, 2 – Low importance, 3 – Medium importance, 4 – High importance, 5 – Very high importance)			
Management searches for sources of new technology within the enterprise		0.4	
Search for external sources of new technology (e.g. analysis of public technology licences, analysis of technical and industry literature, analysis of patents and literature citations)		0.4	
Market analysis for new technologies available for current use in the enterprise		0.4	
Market analysis for new technologies available for future use in the enterprise		0.4	
Establishment of cooperation with external originators of new technologies		0.4	
Searching for new employees for the creation and implementation of new technologies		0.4	
Monitoring the behaviour of competitors concerning the creation and implementation of new technologies		0.4	
Rate the importance of the various conditions relevant to implementing new technologies in Your enterprise in the last three years (2019–2021) (rating on a scale of 1 to 5, where 1 – No importance, 2 – Low importance, 3 – Medium importance, 4 – High importance, 5 – Very high importance)			
Ability to assess technological potential from a market perspective		0.4	
Analysis and assessment of technological potential from the point of view of the relationship with corporate strategy		0.4	
Analysis and assessment of technological potential from the point of view of necessary investments		0.4	
Analysis and assessment of technological potential from the point of view of the possibility of commercialisation of the technology		0.4	

Sheet 3			
List of conditions	**Number of points (1–5)**	**Weight**	**(Number of points) (Weight)**
Analysis and assessment of technological potential from the point of view of the expected return on investment		0.4	
Ability to assess the risk of implementing new technologies		0.4	
Ability to assess the impact of technology on implemented product innovations and business processes		0.4	
Rate the intensity of application of the following approaches to technology implementation in Your enterprise in the last three years (2019–2021) (rating on a scale of 1 to 5, where 1 – None, 2 – Low intensity, 3 – Medium intensity, 4 – High intensity, 5 – Very high intensity)			
Application of the **'watch and wait' approach** – used when a new technology's uncertainty is too great to start researching and developing it. The enterprise waits for developments and creates competitive barriers.		0.4	
Application of the **'position and learn' approach** – used when the uncertainty associated with new technology is low, allowing it to develop and stop the threat from competitors. The enterprise engages with the new technology creating a more active learning process.		0.4	
Application of the **'sense and follow' approach** – used when an enterprise completes the process of identifying and evaluating a technology by deciding to invest in new technology. The enterprise has a good chance of becoming a market leader while pursuing an active commercialisation strategy.		0.4	
Application of the **'believe and lead' approach** – used when new technology opportunities are auspicious, and an enterprise can fully commit its resources to commercialise the emerging technology. The enterprise makes a decision based on the intuition and experience of technology leaders at the cutting edge of technology.		0.4	
Total number of points			

3. Compare the total scores obtained with the ranges shown in Table 2, which represent the respective levels of technological advantage.

Tabela 2. Required number of points for levels of technological advantage

Level of technological advantage	Interval of points
1	5–19
2	20–39
3	40–65
4	66–85
5	86–100

4. The procedure to be followed in the process of building the technological advantage of a SMART enterprise (see Figure 1) allows grouping the conditions for building the technological advantage required for each level. The necessary conditions for each level of technological advantage were divided into sets in terms of their importance (the names of the sets are described in Table 3), which were prioritised accordingly.

Tabela 3. Names of the sets used in the procedure

Name	Description
1STLTA	1st level of technological advantage
2NDLTA	2nd level of technological advantage
3RDLTA	3rd level of technological advantage
4THLTA	4th level of technological advantage
5THLTA	5th level of technological advantage
RCP1	Required conditions with priority 1
RCP2	Required conditions with priority 2

Once the level of an enterprise's technological advantage has been determined, it is positioned at a certain point in the procedure (see Figure 1) so that its current position in the process of building technological advantage can be known. It also makes it possible to check what conditions need to be met to increase the level of current technological advantage. The correct use of the procedure requires the observance of two rules:

- the levels must not be skipped. They can only be achieved successively,
- only after fulfilling the conditions from the given sets for the respective level of technological advantage can one move on to the next one.

1 STLTA (RCP1)
- Possession of basic technologies
- Cooperation with suppliers
- Cooperation with customers
- Cooperation with investors

1 STLTA (RCP2)
- Market analysis for new technologies available for current use in the enterprise
- Market analysis for new technologies available for future use in the enterprise
- Analysis and assessment of technological potential from the point of view of the relationship with corporate strategy
- Ability to assess technological potential from a market perspective

Reached 1st level of technological advantage

2NDLTA (RCP1)
- Searching for new employees for the creation and implementation of new technologies
- Knowledge of technologies currently used by competing enterprises
- Establishment of cooperation with external originators of new technologies
- Monitoring the behaviour of competitors concerning the creation and implementation of new technologies
- Ability to assess the impact of technology on implemented product innovations and business processes

2NDLTA (RCP2)
- Ability to assess the risk of implementing new technologies
- Analysis and assessment of technological potential from the point of view of necessary investments
- Analysis and assessment of technological potential from the point of view of the expected return on investment
- Search for external sources of new technology (e.g. analysis of public technology licences, analysis of technical and industry literature, analysis of patents and literature citations)
- Management searches for sources of new technology within enterprise

Reached 2nd level of technological advantage

3RDLTA (RCP1)
- Possession of core technologies
- Management's willingness to bear the risks arising from the creation of new technologies
- The financial capacity of the enterprise to create and develop new technologies
- Analysis and assessment of technological potential from the point of view of the possibility of commercialisation of the technology

3RDLTA (RCP2)
- Adequate level of the technological potential of the enterprise for the creation of new technologies
- Management competence to create new technologies
- Cooperation with external R&D centres, e.g. universities
- Investment in R&D activity

Reached 3rd level of technological advantage

4THLTA (RCP1)
- Competence of R&D employees in the creation of new technology
- Development of R&D employees
- Conducting R&D activity
- Development of R&D infastructure

4THLTA (RCP2)
- Application of the sense and follow approach
- Application of the believe and lead approach
- Application of the watch and wait approach
- Application of the position and learn approach

Reached 4th level of technological advantage

5THLTA (RCP1)
- Possession of emerging technologies

Reached 5th level of technological advantage

Figure 4.40. Procedure to follow in the process of building technological advantage in SMART enterprises

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When considering the presence of conditions that build technological advantage, it is worth linking to competitive advantage, of which it is a partial advantage. Three dominant forces determining the functioning of SMART enterprises in the market can be distinguished: globalisation, rapid technological progress, and the growing importance of intellectual capital. From the point of view of building technological advantage, rapid technological development is the most significant. The technological advantage is typically associated with SMART enterprises that create and use the latest technologies. The leading role of knowledge, vision management, R&D work, time pressure, core competencies, and critical personnel defines this type of enterprise. It is also characterised by high innovation, global market coverage, and shorter technology life cycles. Key competencies include change and innovation management, intellectual capital management, selection of key personnel, implementation systems, and changes to the market. Therefore, it was decided to select key conditions for building the technological advantage of SMART enterprises, such as technological innovation capability, technology commercialisation capability, technology transfer performance, and technological capacity.

Among other things, the scientific monograph is distinguished by its holistic view of the discussed issues of the conditions for building a technological advantage of SMART enterprises in the age of Industry 4.0 and is therefore intended for the scientific community, entrepreneurs and managers.

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